Research thesis submitted in undertaking MSc Renewable Energy at Murdoch University

Dissertation Title:

Benefits and disadvantages of using a holistic development approach vs streamlined rural electrification programme in using renewable energy to support social development objectives in the Himalayan context.

Author: Mr Terry Roberts BSc, BEng (Hons, first class)

Studying at: Murdoch University, Perth, Australia

Faculty: School of Engineering and Science

Head of School: Dr Trevor Pryor

Supervisor: Dr Tania Urmee

Author's Declaration

I declare that all work undertaken in this research topic, and presented in this dissertation is my own work, and that where data, research analysis and conclusions from others have been used to support my findings, that these have been fairly referenced and acknowledged.

Signature:

Abstract

Based on review of available literature, comparison was made between two programmes (RIDS-Nepal and ADB-Bhutan rural electrification programme) targeted at improving quality of life for Himalayan communities, in order to see how their different approaches to achieving these improvements worked towards meeting similar objectives within similar target audiences.

It was found that each programme approach was well suited to its context of delivery; the ADB-Bhutan streamlined electrification approach is deemed highly appropriate given the context of strong, able government support, and the objective for delivering equity to all populace of Bhutan as rapidly as possible, while the RIDS-Nepal holistic approach delivers amazing results given its overall limitations of resourcing and attendant challenges in delivery. Both were found to have significant impact on their target audience, towards achieving their high level objectives of improving quality of life.

The comparison revealed that the RIDS-Nepal programme had managed to achieve significantly greater relative impact on its target audience in regards to reducing levels of fuelwood consumption, and associated health, social and environmental benefits than the streamlined rural electrification approach. It had achieved this through greater focus on end benefits in programme design and delivery, and through being forced to innovate and consider achievement of high level objectives holistically, given its lower resource base.

The ADB-Bhutan electrification programmes could learn from the RIDS-Nepal experience, particularly in regard to deploying complimentary policy and technology in conjunction, or shortly after electrification. Specifically, greater focus on energy efficiency and support of other options for improving energy services are required in order to make steeper in-roads into reducing fuelwood consumption, and attendant benefits to preventative health, labour burden and the environment.

Examples of this include focus on a wider array of smokeless metal stove/heating options, and support to establish community based bathing facilities, and development of lower cost, safe bulk hot water heating devices. The opportunity to establish internal cottage industries to develop these options may also provide economic advantages.

Acknowledgments

The Author would like to thank Mr Alex Zahnd, founder of RIDS-Nepal, Mr Drukchu Dorji and Mr Norbu Tshering, General Managers of rural electrification and resourcing at Bhutan Power Corporation, for their kind and generous assistance in open discussion on the programmes they so capably deliver.

Table of Contents

0.0 Preface

In undertaking this research, the author acknowledges the potential question of whether comparison between two vastly differing programmes (holistic development programme versus electrification programme) is either fair or valid, particularly given the former is an outcomes focussed effort, whereas the latter is focussed rather towards delivering an enabling mechanism (access to electricity). The author maintains that such comparison is valid, where end objectives and anticipated outcomes of the programmes are core, and in common to each programme.

Fairness or unfairness of comparison is not intended, nor should be perceived as such: the spirit of this work is to see whether there are things the programmes can learn from each other, using the tool of comparison, in regards to outcomes versus objectives and relative effort.

The achievements of both programmes studied in this work are outstanding, and the author would like to express his admiration for these achievements, the governing agencies, and all personnel involved in their delivery, in regard both to their dedication, and effectiveness.

0.1 List of acronyms

ADB – Asian Development Bank
ADF – Asian Development Fund
BPC – Bhutan Power Corporation
DMC – developing member country
FGD – focus group discussion
IEG – Independent Evaluation Group
JICA – Japan International Cooperation Agency
kWh – kilowatt-hour
MDG – Millennium Development Goals
OLS – ordinary least squares
PCR – project completion report
PSM – propensity score matching
PVR – project completion report validation report
RE – rural electrification
RENEP – Rural Electrification and Network Expansion Project (Bhutan)
RGoB – Royal Government of Bhutan
SAARC – South Asian Association of Regional Cooperation
SMS – smokeless metal stove
SREP – Sustainable Rural Electrification Project (Bhutan)
TA – technical assistance
WLED – white light emitting diode
WTP – willingness to pay

0.2 Glossary

Bukhari – fuelwood based house or space heating system with smoke exhaust through chimney
Dzonkhag – district
Gewog – group of villages
Gup – village leader
Nepalese Rupee – currency unit of Peoples Democratic Republic of Nepal; 1Rs ~
Ngultrum (Nu) – currency unit of Kingdom of Bhutan; 1Nu ~ 0.02USD

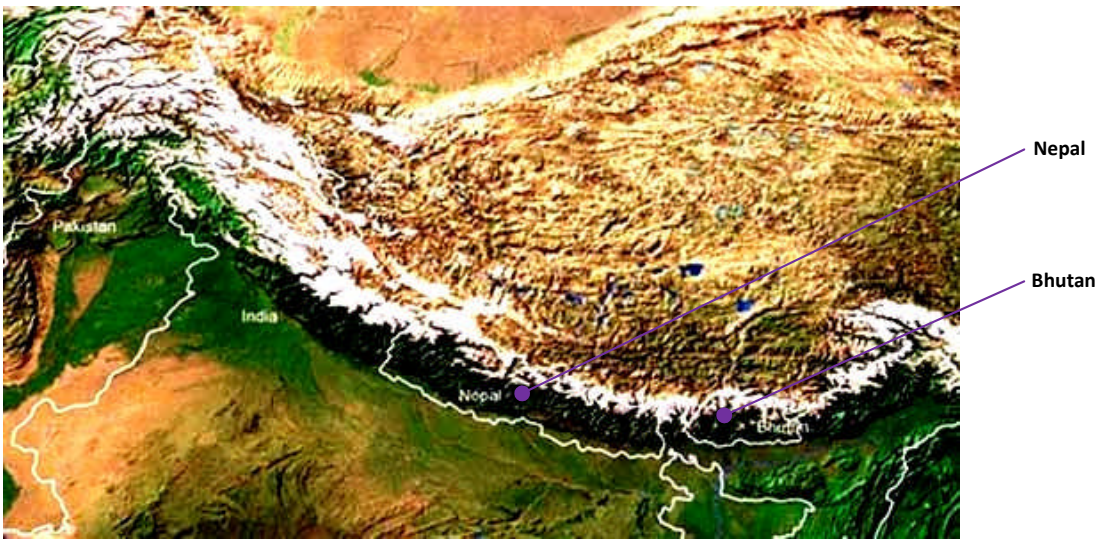
1.0 Introduction

1.1 Context of Research

Rural electrification through grid connection or off-grid provision is widely acknowledged as a key component of development, and alleviating poverty in rural communities.[1] Nowhere is this truer than in the Himalayan region, where remoteness and extremely harsh climatic conditions make access to energy for heating and cooking purposes a key element to survival.

The countries of Nepal and Bhutan are located within the Himalayan mountain range in central Asia. While the countries are of different size and population, they have some striking similarities, including overall range of geographies and climatic conditions, and largely rural populations based on subsistence living. These rural populations are often characterised by small village communities, living remotely from major centres, within the most mountainous region of the world.

Figure 1 – Nepal and Bhutan – situated directly along the spine of the Himalaya



Historically, given the remoteness and challenge of their surrounding terrain, these mountain communities have had almost no access to electricity and other modern energy fuels, and been entirely dependent on traditional energy sources [fuelwood and animal dung] for heat and cooking. This dependence imposes a range of social and environmental issues, including;

- Health Issues [related to indoor air pollution, hygiene access to hot water],
- Labour and Gender Equality Issues [collection of fuelwood is labour and time intensive], and
- Environmental Issues [deforestation, and consequent erosion and loss of biodiversity].

Access to electricity has the potential to alleviate these issues significantly, as well as providing vastly improved access to lighting and communication, with accompanying social and economic benefits through opportunity for earning potential, education and gender equality.

This project will examine the different approaches to rural electrification undertaken in the Himalayan region within the delivery of two specific programs;

- ✧ the RIDS-Nepal program, which employs a holistic community development approach to their projects undertaken within Nepal, and
- ✧ the more streamlined rural electrification program undertaken by the Bhutanese Government, that is funded by the Asian Development Bank (ADB) within the Kingdom of Bhutan (ADB-Bhutan).

The broader intent is to identify the achievements, strengths and weakness of each approach, where they have common, or near-common goals, and where each program can learn from the other, to better achieve their goals.

1.2 RIDS-Nepal and ADB-Bhutan Programmes

Both RIDS – Nepal and the ADB rural electrification program in Bhutan [ADB-Bhutan] seek to deliver improvement in living conditions at residential and community level, within their rural populations. Both use elements of renewable energy generation and provision of electricity in order to achieve this, but their approach, and the financial and government supporting context in which these programs operate, can hardly be more different.

RIDS - Nepal

The RIDS-Nepal program is delivered within the remote Upper - Humla district of Nepal. Its approach is constructed to achieve a long term, community owned response, and is delivered within an environment where;

- government support is lacking: Nepal does not have a government closely focussed on electrification amongst other priorities, nor the revenue means to support such ambitions;
- community financial capacity is very low, and;
- external funding is usually limited to individual project deployment rather than program development, and with little or no support for follow-up.

The program places small scale deployment of renewable energy technologies [RETs], alongside other critical residential and community projects. This approach is partially set by the constraints that Nepal presents, but it is also a very deliberate design intent in order for projects to be owned by recipient communities, and therefore sustained within communities where they are rolled out.

The approach is holistic, in that it does not regard electricity, or energy services as the central objective, but as a key element within a raft of community improvement mechanisms. This is in order to;

- achieve greater buy-in from the community, by creating multiple benefits that are more easily identified and valued by recipient communities,
- ensure that most critical community needs are met in order of priority,
- realise synergistic benefits between measures, and
- maximise the potential benefits of each of the measures undertaken.

The specific structure of RIDs-Nepal project commences with the “Family of 4” projects within a village, which can be followed by “Family of 4 PLUS” additional projects. They commence in project

order such that the most crucial needs of a community are delivered first. The Family of 4 is designed to deliver, in sequential order;

1] Residential/community pit latrines
2] Smokeless metal stoves (SMS)
3] Solar or pico-hydro based WLED lighting systems
4] Delivered Tap drinking water for village.

Extension projects, in Family of 4 PLUS, can be more flexible in sequence of delivery, and can include projects such as: greenhouse for improving food growing, electric charging for communication devices, and communal hot water services based on solar or pico-hydro systems.

RIDS-Nepal founder, Alex Zahnd estimates that RIDS-Nepal Family of 4 has been implemented in over 100 villages over the past 25 years, which is likely to represent more than 10% of the population in Humla.

ADB-Bhutan

In contrast to the holistic approach, the approach taken in Bhutan, including the program component sponsored by the ADB, is focussed purely on rural electrification, with the expectation that the related benefits to communities will follow naturally. The ADB sponsored approach is also highly centralised, providing grid extension and connection where feasible (with power supplied by large scale hydroelectric generation), and off-grid renewable solutions (mostly solar PV) where it is not. Backing this program and approach are;

- Firm Bhutanese Government target for 100% electrification as soon as possible, and strong implementation support;
- Ability to sustain significantly subsidised residential electricity consumption long term, through power export revenue to India (India also provides investment for hydro generation asset build, takes the lion share of resulting power generation, and effectively subsidises domestic Bhutanese power consumption);
- Generous ADB loan support and knowhow.

These conditions favour this streamlined approach to a larger extent, and should offer recipe for success. This is indeed reflected in the successful rapid roll-out of the ADB-Bhutan program – initial projects sponsored by ADB have witnessed the electrification of over 20,000 households[2], and remaining ADB projects target a further 13,842 households[3], a combined reach of approximately 40% of Bhutan's population.

While rural electrification in the ADB-Bhutan Program and in other similar partner programs in Bhutan has been rapid, in review the ADB has noted positive impacts, but to a significantly lesser extent than they had forecast. They have recommended complimentary government policies (such as imposing a tariff on collecting firewood) to amend this.

It appears that in maximising the Program's reach and speed of delivery, that it has inadvertently sacrificed some of the potential benefits of electrification.

Similarities between RIDS-Nepal and ADB-Bhutan and limitations

While their approaches are different, and suit differing country contexts, these two programs seek to deliver the same ultimate benefits within a community context that is strikingly similar in regard to: culture, geography, terrain, climate, energy resource, level of wealth, livelihood and needs. Consequently, background objectives for both programmes are very similar, even if approach and specific goals vary.

Both Bhutan and Nepal have been host to many rural electrification programs, primarily run with the aid of external partners, and faced with the same unique challenges of the Himalayan environment. This affords the ability to compare and contrast programs run within these countries.

Limitations to this comparison exist in regards to the scopes of individual programs, and the support frameworks they have available to undertake programmes. Supporting framework is a key factor to successful programs, and includes internal government support (willingness and capacity to finance), and/or external financing or revenue that exists, and the sustainability of these supporting options. For this reason, detailed contextual overview for electrification programmes will be provided for each country, in sections 2.1.1 to 2.1.3.

1.3 Specific Objectives of this Research

The overall objective of this research is to improve understanding of the trade off that exists between a (holistic) development program's attempt to maximise potential gains associated with electrification, compared with a (streamlined) program's speed of deployment and reach. Does the streamlined approach extract enough of the potential benefits associated with its deployment, so justifying its more rapid deployment and effective reach? Or conversely, does the holistic approach extract sufficiently more benefit to justify its slower deployment?

The above questions are subjective and are unlikely to possess definitive answers. With this in mind, the intent is to identify the achievements, strengths and weakness of each approach, where they have common, or near-common goals, and where each program can learn from each other, in order to better achieve their goals.

In order to do this, the research will focus on finding answers to more specific questions. The primary focus question for this research is:

"How well are the main benefits that are commonly cited as resulting from electrification realised by each program and how sustainable are these programs?"

Specific questions to support this evaluation include;

A] To what extent is the uptake of fuel switching or improved energy service options in each program realised in regards to;

- lighting
- heating & cooking
- hot water
- communications

B] To what extent are the associated benefits of this uptake realised, considering;

- health and hygiene
- reduced fuelwood consumption
- freeing up time and supporting education and economic activities
- community benefits

C] To what extent the programs are sustainable in terms of

- operation and maintenance of the technologies/systems involved
- community engagement and ownership of the improvements
- financial and technical ability to replace equipment hardware
- sustained realisation of achieved benefits.

2.0 Background

2.1 Country Context

Nepal and Bhutan are located on the southern spine of the Himalayan Range in central Asia. Both are landlocked countries, encased by long mountainous borders with China to the North, and by India on all other sides. The countries range in elevation from well above 7km, along the highest mountain range in the world, down to around ~100m above sea level in the southern plains. Much of the populated landmass in both countries exists in the Himalayan foothills, with habitation above 1500m – amongst the most rugged and mountainous terrain in the world.

The Nepali land area is around four times the size of nearby Bhutan, and hosts a population nearing 30 million. Nepal is one of the poorest and least developed countries in the world, with nearly a third of its population estimated to be below the poverty line.[4] Agriculture underpins the economy, and employs almost ¾ of the workforce, in delivering around a third of GDP.[5]

People-wise, Bhutan has a far smaller population than Nepal (~ ¾ million people), that is also largely reliant on subsistence farming. Similar to Nepal, much of the rural population is geographically dispersed, and living conditions due to climate and terrain are challenging. While poverty levels remain high (estimated 23%), the Bhutanese government has made significant and rapid progress over the past few decades to reducing poverty levels, and increasing GDP while retaining high levels of protections for Bhutan's environment and culture.[6]

This has been achieved through careful expansion of high end tourism and hydropower export industries, and delivery of model educational, social and environmental programs.[7] These have contributed to significant increases in GDP per capita, to an estimated $6000 in 2011; well over four times the wealth to population ratio that exists in Nepal.

The Bhutanese government has made positive progress in increasing GDP as it has significant hydropower resource coupled with a supportive and electricity hungry trade partner in India, and a tourism market that values its efforts to preserve culture and environment. Most crucially, the Bhutanese government has been stable, strong and focussed, and determined to avoid many of the pitfalls of developmental progress witnessed by other countries in Asia. Improvement to GDP has yielded positive impact across the majority of the Bhutanese population, due to focussed government efforts to deliver health, education, transport and communications programs, and as the population is relatively small.

Like Bhutan, Nepal has significant potential with regards to hydropower, and a well developed tourism industry. By contrast however, the Nepali government has been far from stable, with the assassination of most of the Royal Family in 2001 occurring in the midst of armed insurgency which bedevilled the country for almost a decade between 1996 and 2006.[8] Even post 2006, after peace accords were struck with Maoist insurgents and government formed with representation from all parties, continued instability [repeat elections and civil disruption] has ensued.[9]

As a result, Nepal's tourism industry has suffered, and it has been unable to make progress in exploiting its own significant hydropower potential. Few of the ambitions the government has held

for improving the living conditions for its peoples have been realised, and in general, it is regarded that living conditions in Nepal have deteriorated as a result of the war.

This has extended to Nepal's ambitions for rural electrification, which have suffered delay and setback in recent times, in contrast to Bhutan's rapid progress over the past decade, as discussed in the next section.

A fuller comparison of country statistics are contained in Table 1 below.

Table 1 – Country Statistics of relevance for Nepal and Bhutan, as published in CIA World Factbook[10]

	Nepal	Bhutan
Landmass	147,181 sq km	38,394 sq km
Terrain	Tarai or flat river plain of the Ganges in south, central hill region, rugged Himalayas in north	mostly mountainous with some fertile valleys in the North, stretching into sub-tropical, tropical and savanna in the South
Population	29,890,686 (July 2011 est.)	716,896 (July 2012 est.)
Culture: **1] Ethnic Groups** **2] Religion**	1] Chhettri 15.5%, Brahman-Hill 12.5%, Magar 7%, Tharu 6.6%, Tamang 5.5%, Newar 5.4%, Muslim 4.2%, Kami 3.9%, Yadav 3.9%, other 32.7% 2] Hindu 80.6%, Buddhist 10.7%, Muslim 4.2%, Kirant 3.6%, other 0.9% (2001 census)	1] Bhote 50%, ethnic Nepalese 35% (includes Lhotsampas - one of several Nepalese ethnic groups), indigenous or migrant tribes 15% 2] Lamaistic Buddhist 75%, Indian- and Nepalese-influenced Hinduism 25%
GDP	$37.74 billion (2011 est.)	$4.284 billion (2011 est.)
GDP per capita	$1,300 (2011 est.)	$6,000 (2011 est.)
Natural Resources	Quartz, water, hydropower, small deposits of lignite, cobalt, copper, iron ore	timber, hydropower, gypsum, calcium carbonate
Population estimated below poverty line	30.9% (2011)	23.2% (2008)
Life Expectancy	66.51 years	67.88 years (2011 est.)
Irrigated Land	11,680 sq km (2003)	400 sq km (2003)
Total Renewable Water Resource	210.2 cu km (1999)	95 cu km (1987)
Freshwater withdrawal (domestic/industrial/agriculture)	10.18 cu km/yr (3%/1%/96%)	0.43 cu km/yr (5%/1%/94%)
Freshwater withdrawal Per Capita	375 cu m/yr (2000)	199 cu m/yr (2000)
Environmental Issues	deforestation (overuse of wood for fuel and lack of alternatives); contaminated water (with human and animal wastes, agricultural runoff, and industrial effluents); wildlife conservation; vehicular emissions	soil erosion; limited access to potable water ; over-border poaching of native fauna endangered in the region
Electricity Consumption	4.833 billion kWh (2010 est.)	184 million kWh (2009 est.)
Electricity Production	3.156 billion kWh (2010 est.)	11.48 billion kWh (2009 est.)

2.1.1. History of goals and progress toward electrification

Nepal

The Nepalese Government had identified the need to reduce dependence on traditional energy forms [primarily fuelwood], as early as the mid nineteen-eighties.[11] This recognition had been forced by environmental concerns over deforestation, and was to be addressed through significant expenditure to support policy objectives in the Country's Seventh Five Year Plan, focussed on;

- Development of Biogas usage at household and village level
- Development of microhydro and hydel capacity

- Development of higher efficiency wood stoves.

By the early 1990's, Nepal had identified a total Hydro potential of some 83 GW, of which 42 GW could be developed, based on economic feasibility studies. This potential, the recognition that only 9% of the populace had access to electricity, and the growing need for reducing dependence on fuelwood had formalised into a more significant Rural Electrification Program.[12]

The goals of this program were to gradually electrify the rural areas where the majority of the Nepalese population lived, through development of hydropower and extension of the existing grid system, and complimentary development of micro hydro and hydel projects to more remote rural areas. At this juncture, the program was tasked to provide electrification to some 950,000 of the rural population, across 1200 villages by 1997-8, financed by the Nepalese Government to the tune of 18 billion Rs, including significant continued support from the ADB[i].[13]

Significant challenges to these goals were also identified within the Eighth Five Year Plan. Approximately 30% of the 238 billion Rs required for power generation projects to underpin resulting increase in demand, was required from the private sector. The Nepalese government would be substantially dependant on external funding for the remaining 70%, and had found previously that "It has not been possible to generate electricity at stipulated time and cost due to delay in the implementation of the project resulting from the lack of synchronized financing by multiple donors".[14] Even if successful in lining up capital for future large scale hydro generation, the Eighth Five Year Plan foreshadowed that 20-30% shortfalls in power supply would still occur over the coming 5-6 year period.[15]

By the Tenth Five Year Plan, Nepal's stated ambitions for electrification had increased significantly. In March 2002, the Plan stated long term targets to provide electricity to 80% of the populace, 63% through further extension to National Grid, and 17% via alternate solutions, including Hydel and solar lighting systems. The five year targets were to extend National Grid provision to a further 10% of the population, and off-grid solutions to a further five percent.

Country political and civil instability appears to have thwarted detailed review of progress in the intervening period up until release of the Tenth Five Year Plan,[ii] which reported that 40% of the Nepalese population had *some* access to electricity as of 2002, which included 57MW of solar PV generation.[16] Little credible detail or backing for the figure was found in this literature review, though it is apparent that some significant progress had been made in increasing hydro generation capacity, deployment of solar PV based lighting, and in extending National Grid during the preceding decade.

By August 2010, and the release of the government's 2011-2013 Interim Plan, the power supply deficit identified nearly 20 years earlier had become critical, with load shedding of up to 12 hours a day occurring frequently.[17] Despite this inability to meet existing grid customers, the targets for rural electrification have been extended further – an extra 10% of the population are to be added to the National Grid by 2013.

This brings the Government projection of total Nepalese population with National Grid connection to 58.5% by the end of 2013 Financial Year, with goals extending to 75% by 2027. Twenty billion Rs

[i] Financing from the sixth and seventh power projects funded by the Asian Development Bank [as reported in Chapter 16, Eighth Five Year Plan]
[ii] the Ninth Five Year Plan had enunciated only that, "Rural electrification has become urgent"[ii]

have been committed toward achieving the Transmission, Distribution and Connection costs to achieve the 2013 target, but only ten billion Rs towards the mid-large scale hydro generation required to meet demand.

There is also a planned roll-out of non-grid provision, in the form of micro hydro, hydel, Solar Home System (SHS), and solar lamps, to an additional 7% of remote population that is committed within the 2011-13 Interim Plan. The Plan estimates that ~9% of the Nepalese population have already been provided some access to electricity by such means, including connection of 88,000 solar home systems and distribution of 60,000 solar lamps to rural populace during the 2008-10 period.

There is no mention or review of how successful or sustainable the off-grid provision already implemented within Nepal has proven. The interim plan does not appear to count the estimated 9% of population already provided with off-grid electric lighting within its 2013 projection of total population that will have some access to electricity [65% total, including 58.5% projected to have national Grid access, and an additional 7% with off-grid electricity]. Perhaps this is tacit admission that prior off-grid provision cannot be counted towards projected totals, where the government has conducted no follow-up review of operational success.

Precise figures for those with access to electricity currently are difficult to find, but in the 2010-11 Annual Report the Managing Director has provided the following statements, in relation to access, and realisation of the unsustainable nature of continued electrification policy;

"Despite having a century long history of electricity generation and consumption, half of the population is still deprived from use of electricity and other half is facing long hours of power cut", and;

NEA[iii] has been finding itself uncomfortable with the net loss making business of rural electrification. It is realized that NEA cannot afford its scarce resources in this social activity as well as it cannot continue to provide bulk electricity to communities at a price much less than its purchase tariff. Idea of establishing a Rural Electrification Company has been floated which we wish to come to reality. Similarly, huge investment on grid expansion is not financially justifiable to NEA's balance sheet."[18]

Since this statement and targets set in mid 2010, the most recent estimate found is from April 2012, which reported an estimated 56% of Nepalese households having access to electricity for lighting.[19]

Bhutan

The pressing need for rural electrification was recognised within the Kingdom of Bhutan at a similar time to Nepal, but with slightly different drivers. While reduction of fuelwood was a driver that fit well with the King's long sighted environmental protection policies, Bhutan's population is very small in relation to forest cover, so the environmental imperative was less urgent than in Nepal - economic and living standards were the primary motivation. Bhutan's first significant Hydro Generation was commissioned in 1987/88, with most of the power exported to India. In doing so, it almost immediately boosted Bhutan's net exports to India by 30%, and the Bhutanese economy by 10% of GDP.

In realising this first element of hydropower potential, the Government viewed this as opportunity to improve living standards within the country: "Electricity is seen, at the present time, not as a revenue earner but as an essential commodity that will improve the living conditions of the common

[iii] Nepalese Electricity Authority

man affordable by him so that he can consider further usage to enable economic growth"[20]. This became a matter the Bhutanese were determined to address; in the early 1990's, its people were one of the most highly fuelwood dependent populations in the world, with over 90% having no access to electricity.[21]

This was enunciated in Bhutan's Eighth Five Year Plan – which included prescient goals to provide as much electrical energy to all parts of Bhutan as possible. This would be achieved through the establishment of National Grid, and provision of off-grid solutions [envisaged as solar, microhydro and hydel], where remoteness rendered grid extension impractical.[22]

By December 2000 hydro generation capacity of between 350MW – 400MW had been commissioned, and the government had achieved connection to over 28,000 urban and rural households[23], estimated at 35% of the population. Moreover, the King had established the goal for 100% electrification to be achieved by 2020.[24] Five year electrification targets were significantly accelerated in order to achieve this, and with significant increase in support funding from JICA[iv] and ADB for electrification.

In 2007, the 1020MW Tala hydro project had been completed, more than trebling Bhutan's hydro capacity to nearly 1500MW, and boosting the electricity sectors share of GDP to 20%.[25] Power exports to India were now responsible for more than 45% of overall export revenue and this was providing a sustainable subsidy for domestic power pricing policy.[26] Successful large scale hydro development had paved the way for Bhutan to effectively implement its Rural Electrification Master Plan (REMP), jointly developed with JICA in 2004-5.[27]

The rapid growth of Bhutan's electricity sector had led to structural changes, and the Rural Electrification Program designed to implement the Master Plan had become the auspice of the newly formed Bhutan Power Corporation (BPC).[28] With an estimated 54% of rural Bhutanese households having access to electricity by 2007[29], BPC brought forward the 100% electrification timeframe to 2017 after conducting detailed feasibility on how to implement the Master Plan.

The Government of Bhutan transformed to a full democracy in 2008. Democratisation brought further acceleration of government goals on improving living standards for the population, and on enacting environmental protections. The goal for 100% electrification was brought forward to being achieved by 2013. In order to do this, BPC estimated it would need to provide electricity to nearly 44,000 more rural households, including; grid extension to over 34,000 households, fill-in connections to over 6,000, and off-grid renewable based solutions for ~3,700.[30]

Interim assessment of the plan showed that 82% of the funding required to achieving this had been secured, covering 86% of households yet to be electrified.[31] Progress toward implementing the plan has undergone manageable delay only, due to project implementation factors [including weather, materials and construction delays], and has been steady. The Ministry of Energy reported that further funds had been secured to close the funding gap previously reported, and all major electrification projects were progressing well in its Calendar Year Annual Report for 2010. By January 1 2011, it was reported that overall, 73% of all households now had access to electricity.[32]

[iv] Japanese International Cooperation Agency

Intervening Factors

The intentions of the Nepalese Government toward implementing internal energy policy, including all electrification objectives have been hamstrung by the decade long internal conflict that blighted the country between 1996 and 2006. In this time, the government estimates that over 11,000 people were killed, more than 3,500 families displaced, another 1000 people missing, and over 5 billion Nepalese Rupees worth of damage inflicted to public/civil infrastructure.[33]

The damage and disruption that this conflict brought to the country almost completely destroyed any internal government efforts towards social and economic development during this period. The energy sector was hit as hard as any other, with no useful progress on developing Nepal's considerable hydropower export potential.

Furthermore, the government has been fragile in the conflict's aftermath, and its focus since the end of the conflict has mostly been consumed on reparation to civilians affected by the conflict, before it can re-commence its longer term development agenda. The Nepalese government has prioritised reconstruction and rehabilitation in its post-war Three Year interim plan of 2008-2010, including committed over $5 billion Rs towards reconstruction and rehabilitation programmes in this period.[34]

In contrast to the internal conflict in Nepal, Bhutan has witnessed exceptionally stable Monarchy and government throughout the past decades. The country changed governance structure to a constitutional Monarchy shortly after His Majesty Jigme Khesar Namgyal Wangchuk's accession to the throne in 2008. The Royal Government of Bhutan (RGoB) has retained strong focus and capacity to progress its social development agenda both before and after this transition.

2.1.2. Summary of overall progress in electrification and current targets

In comparative terms, it must be remembered that the scale of the task to provide domestic electrical services in Nepal is far greater than in Bhutan, given Nepal's significantly larger land area, and also population. In light of this, both Nepal and Bhutan have made significant progress toward improving access to electricity for their populations.

In terms of percentage of the population with access to electricity, Bhutan has managed to set ambitious target of 100% by 2013, and looks on track to meet these goals, whereas Nepal has set much lower and longer timelines, and is struggling to meet these. In sheer numbers however, Nepal has managed to provide some level of access to electricity to over half of its population (>15 million people); many times the entire population of Bhutan. Overall progress over the past two decades is mapped in Table 2 below.

While the number of additional people provided with grid access in Nepal looks impressive, other factors must be considered in assessing this progress. Although grid extension and connection has progressed, hydropower development to underpin power supply has not. Nepal's theoretical hydropower generation capacity was estimated at around 688MW in 2010[35], but question exists as to how much of this can be counted as reliable generation capacity.

What is clear is that Nepal's real generation, even when augmented with power import from India, is insufficient to meet demand. The government has identified a deficit of nearly 400MW in the dry

season that results in massive load shedding of up to 12-16 hours per day even in Nepal's capital (Kathmandu).[36] This means that while many now have electrical connection, reliability is poor and supply is expensive.

This lack of reliability and expensive unit costs for the domestic population have contributed to Nepal still witnessing almost the lowest electricity consumption per capita statistics in Asia. Furthermore it is likely that electricity consumption for those with grid access has fallen over the past decade, and will continue to fall.

Meanwhile those rural Nepalese provided with off-grid systems by government facilitated programs, including community mini-grid, SHS and solar lamps, are not supported beyond initial provision and installation. The ability of these peoples to maintain and replace such systems is questionable.

In contrast to this, Bhutan has been successful in developing large scale hydropower projects, and has current generation capacity more than double Nepal's, for a fraction of the population. This means that the vast majority of power is exported to India and raises revenue. This is used to subsidise electricity costs for the domestic population, for both on and off-grid users; the latter are supported with respect to maintenance and parts for mini-grid and community based systems.

Table 2 – Progress in Electrification

	Nepal	Bhutan
Estimated access to electricity (1990)	9% [June 1992 – 8th FYP]	<10% [1992 – 7th FYP]
Estimated access to electricity (2000)	40% [March 2002 – 10th FYP]	35% [December 2000 – 9th FYP]
Estimated access to electricity (2010)	48.5% [August 2010 - 3yr interim FYP]	70% [December 2010]
Current Goals	65% by 2013* 100% by 2027**	100% by 2013
Estimated per capita electricity consumption per annum	76kWh [August 2010 - 3yr interim FYP]	180-240kWh
Generation Capacity – Hydro [2008]	604MW	1488MW
Electricity Consumption	4.833 billion kWh (2010 est.)	184 million kWh (2009 est.)
Electricity Production	3.156 billion kWh (2010 est.)	11.48 billion kWh (2009 est.)

**58.5% National Grid, 7% Non-Grid*
***75% National Grid, 20% small Hydro and Hydel, 5% SHS/Solar Lighting/Wind*

2.1.3. Overall desktop survey of programmes considering type, financing & coverage

A significant number of electrification programmes have been undertaken within both countries. These have included those focussed on providing full electrification by;

- Extension and Connection to National Grid
- Installation of mini-village grids
- Provision and installation of Solar Home Systems [SHS]
- Provision of solar lamps.

The first of these options is a government undertaking, achieved primarily with significant portion of financing from external donor agencies. Full electrification by grid connection for domestic residence usually offers a household access to more power than it can use, and limits to subsequent living standard improvements usually are encountered through;

1) Ability of connected households to afford devices running off the national grid, and
2) Ability of households to pay for electricity consumption.

A third limitation that occurs on a community/population level is grid stability and reliability of supply, as has been witnessed in Nepal.

Mini-Grids are usually based on hydro, hydel or solar PV in Nepal and Bhutan. These enable provision of varying level of power capacity to households and local community facilities, such as schools and communications nodes. In the context of Nepal and Bhutan, electrical services supported by mini-grids can range from provision of lighting only, up to higher capacities that can support devices for boiling water, rice cookers, communication [including radio and television], laptop computer, and even small scale heating.

Solar Home System and solar lamp programmes focus on provision of electric lighting to households, although SHS extend to support further low powered usage, such as radio, laptop and phone charging. The main benefit of these solutions is access to electrical lighting service, that offers superior lighting quality to traditional lighting forms such as candle, Jharro stick or oil lamp.

Sample of Programmes and support in Nepal

Electrification programmes have been a strong focus for the Nepalese government since the critical issues of de-forestation was realised in the early 1980's. Initial programmes were entirely focussed towards grid extension, and establishment of off-grid microhydro power supply for areas with most severe deforestation concerns.

International donation has been key in this area with strong support provided by the ADB and World Bank, amongst other international funding agencies. Technical assistance, funding and soft loans were available to Nepal throughout the 1980's and 1990's to aid in development of larger scale hydropower development, transmission and distribution, and grid connection.

A full listing of ADB sponsored programmes in Nepal is provided within Appendix 5, however, it is extremely hard to follow or track the running and success of individual programmes, given the disruption that ensued with civil insurgence through 1996-2006. What is clear is that through this time, a large number of programmes were suspended or ceased, particularly those focussed on hydro generation that was to underpin demand of increased electrification, as no significant new hydro-generation has emerged in Nepal since the early 1990's.

The conflict also resulted in an increased presence of non-government sponsored SHS lighting/ electrification programmes in the 1996-2010 period, delivered by NGO's operating within Nepal with external funding support, including RIDS-Nepal. Many of these NGO's now operate with direct Nepalese government support.

This has resulted in a significant shift in government sponsored focus towards more rapid implementation programmes, including distribution of solar lamps and SHS lighting, and improved efficiency fuelwood stoves.

Sample of Programmes and support in Bhutan

Electrification programmes have been a strong focus for the Government of Bhutan since the 1980s, and have received strong support from a number of international donors. Primary amongst these contributors have been the Asian Development Bank (ADB), the Japanese International Cooperation Agency (JICA), the Austrian Government through the ACB[v], and the governments of India and the Netherlands. This support has included both direct funding for project implementation (past and present), and also expertise, training and strategy development for of electrification programme.

Initial focus for electrification included development of microhydro off-grid solutions, and provision of SHS systems for schools, monasteries and other community aspects, usually undertaken with external donor support. This approach was guided by practicality – the vast majority of the rural populace had no road access, so grid extension and access would take decades to be realised.

An example is the development of the Rukubji microhydro project, a 20kW generation project, commissioned in 1985, with strong Japanese technical and financial support. The generation plant [cross flow Kubata Turbine, pictured below], has provided electricity to 101 households in three villages for over 25 years. This mini-grid provides low level electrical services to these communities; sufficient to allow electric lighting, communications devices and low level cooking [rice cooker] for all households.[vi]

Figure 2 – Rukubji 20kW hydropower generation plant [source; author, March 2012]

These initial programmes met with mixed success – it is reported that 2,387 solar PV systems with total installed capacity of 245kW had been installed to 2005, with an average system size of 103Watts[37] – however these systems were often undersized, mismatched to load and resource, and had poor reliability.

The microhydro/Hydel systems were reliable, but running costs exceeded electricity revenue, and daytime demand could not be met, while excessive night time generation went unused. This initial

[v] Austrian Coordination Bureau

[vi] The author had the privilege to visit the Rikuju Hydroelectric plant as guest of BPC.

experience appears to have coloured the Bhutanese approach away from off-grid solutions – in the current planning they are to be employed only where grid electrification is practically impossible.[38]

Centralised electrification effort commenced in the 1990's with strong support from the Indian Government, who had provided strong financial support for initial large scale hydropower generation development, and also technical and financial support for initial electrification programmes.

The ADB commenced financial support for electrification programmes in Bhutan in 1995, contributing[vii] $6.64millions USD loan towards total project costs of $8.21million USD, in order to heavily subsidise the Government's grid connection costs to 3,120 households, including the distribution of 567 electrification kits.

Further ADB funded programmes followed from this, including:

- The $11.6 million USD Sustainable Rural Electrification Project (SREP) in 1999 – January 2006, also designated ADB-II, in which ADB contributed $9.0 million of loan in order to provide grid extension and connection to ~8,100 new households, plus 100 solar panels to monasteries and community centres, and;
- The $13.2 million Rural Electrification and Network Expansion Project (RENEP) in 2003 – December 2006, also designated ADB-III in which ADB financed $8.7 million in order to provide grid extension and connection to ~9,200 new households and community connections.

These projects were delivered in conjunction [further technical and financial support] with the governments of the Netherlands and Austria. They are subject to further analysis in section 5.0.

The ADB has since provided further programme support, under the banner of the Green Power Development Project, which entails finance of $80million USD towards further large scale hydro generation development [Dagachlu Power project], and ADF Grant of $25.28 million for rural electrification for a further 8,676 households (ADB-IV), and 119 solar systems provided to remote schools, community hospitals and other facilities. The Bhutanese government is continuing to invest heavily in extending hydro generation capacity and grid extension within this project, both directly [>$60million direct contribution] and through further commercial loans provided by Austrian Central Bank Credit Agency and Tata Power.

Rural electrification is now coordinated and carried out by the Rural Electrification Department of Bhutan's implementation agency, the Bhutan Power Corporation (BPC). BPC conducts detailed feasibility and project specific implementation to follow the Rural Electrification Master Plan (REMP) that was jointly developed with JICA in 2005.[viii]

Current programmes in Bhutan focussed on achieving the Tenth Five Year Plan target of completing to 100% electrification by end of 2013 include projects sponsored by the ADB, JICA, ACB, and internal funding from the Government of Bhutan or Bhutan Power Corporation (BPC). These projects, in various stages of implementation (some are almost completed), are displayed in Table 3 below;

[vii] Provided from the Asian Development Fund

[viii] "The integrated master plan study for dzongkhag-wise electrification in Bhutan" known as the "REMP"

Table 3 – Current Electrification Projects in Bhutan

Project	Type	Households	External Funds [millions Nu]	Internal Funds [millions Nu]
ACB-VI	on-grid	800	102.94	31.2
ACB-VII	on-grid	219	65	26.082
ADB-IV	on-grid	8,767	1,095.89	287.844
ADB-V	on-grid	5,075	607.2	83.72
JICA/JBIC-I	on-grid	15,712	1,439.34	840.46
JICA-II	on-grid	3,665	905.861	146.275
Micro Hydro	mini-grid	112	58.76	-
RE - Fill-in	on-grid	6,019		501.583
Solar	off-grid	3,582	131.68	-
		43,951	4,407	1,917

Summary of programmes and support in Nepal and Bhutan

Overall, the electrification programmes in Bhutan have consisted of a streamlined approach to rural electrification, primarily focussed on grid extension and connection, with off-grid solutions provided only when community populations are too small and distant to justify grid extension. It has been based on large scale centralised renewable energy development, with small scale renewable energy technologies used in complement.

This approach has been heavily supported by generous funding support from donor agencies – over 1989-2009, 16% of total ADB technical assistance projects grants funding for electrification was provided to Bhutan (12% to Peoples Republic of China, 11% to India).[39] It is underpinned by commercial hydro generation development, which affords Bhutan's government the ability to subsidise its internal grid extension and connection costs, and energy consumption costs for all domestic consumers.

Time will tell if these subsidised power prices can be sustained in terms of operation and maintenance of one of the most geographically ambitious grid networks in the world, or whether more off-grid solutions could have been employed as more efficient long term solutions displacing some of the grid extension and connection carried out in Bhutan. Nevertheless, a stable and focussed government has offered favourable conditions for supporting a streamlined programme approach, and attracting and coordinating the financing to realise it.

In contrast to this, Nepal has been far from stable internally, and hence has not been able to attract the commercial credit inputs required to develop its large scale hydropower potential. Despite this, it has persisted in focussing much of its effort on grid extension and connection, based largely on donor agency funding, without the means to meet the supply of power that this brings.

Furthermore, the geographic and population size of Nepal has required a much greater focus on off-grid solutions to complement grid extension and connection. Again, these projects have been based primarily on donor agency funding, with the result that mini-grid and household [SHS, solar lamp]

based solutions are delivered relatively ad-hoc, in line with funding availability and provision, with little or no follow-up to ensure that programmes have sustainable success.

The RIDS-Nepal programme approach is designed to try and overcome some of these limitations in operating environment in Nepal. It attempts to embed its provision of low consumption electrical services within a raft of community benefit measures, to try and maximise benefits, and achieve ownership of measures by the community. This is quite different from the majority of electrification projects run in either Nepal or Bhutan.

2.2 Objectives and Benefits of rural electrification

Objectives and expected benefits from rural electrification are often confused when evaluating programme success.[40] Programme objectives, both high level and specific, should be purely aligned with achieving and maximising the benefits and outcomes to rural recipients - that justify the programme in the first place - within budgetary and technical capacity.

Achieving objectives can however become over-emphasized in programme design, implementation and evaluation, to the detriment of focus on actual benefits. Though inadvertent, this occurrence frequently compromises a programme results. Urmee et al found that program success could be improved by specifying programme objectives in terms of outcomes to system users, rather than in broad administrative objectives.[41]

Still worse outcomes ensue when objectives are completely misaligned with benefits to recipients.

Misalignment most commonly occurs when objectives are hijacked by external forces, such as political motivations, or worse still corruption. An example is when programmes are constructed to fulfil political promise made by governments, such as to provide rural connection to national grid, irrespective of whether this presents a sustainable option, or is even the best technical and economic electrification solution available. This in turn can result in overloaded grids subject to load shedding, or costs to rural consumers that are well beyond their means. In this example, actual benefits to end-users are usually not achieved let alone maximised, even where programme objectives of grid connection are met.

Objectives

High level objectives of rural electrification policy in the developing country context are almost universally similar, and the most commonly cited aims are[42];

- To improve standards of living for rural communities (including health and social aspects), and to;
- To foster development of rural communities through access to modern energy forms.

These are consistent with the UN's recognition that access to modern energy is key to reducing poverty, as enunciated in the Millennium Development Goals. Further high level objectives often include;

- To reduce inequity between urban and rural populace
- To reduce urban drift [the migration of rural populace to cities],
- To reduce rural environmental impacts, in particular deforestation.

Specific objectives vary with how a programme is designed to achieve these goals, and vary widely between national grid programmes, where the specific objectives include access to grid connection, and increasing average rural electricity consumption metrics, through to solar lamp programmes, which focus on provision of higher quality lighting and perhaps support of handheld device charging.

Best practice specific objectives are closely linked and even seek to enunciate intended benefits and outcomes to system users.[43]

Benefits

While specific objectives vary according to programme type and ambition, intended benefits to rural populace follow the same overall theme, as all programmes are designed to promote the same high level objectives. Consistent with improving standards of living and alleviating poverty in rural communities, the specific potential benefits that access to electricity provides include;

- Access to lighting services/better quality lighting services
- Access to electricity based cooking services
- Improved access to communication (recharge for mobile telephony)
- Accesses to other labour and time saving appliances
- Ability to use electric devices for education and income generating activities (such as computer, and electric motor based tools)

These provide a range of related social, economic and environmental benefits. Those most commonly identified[44,45] include;

- Availability/increased quality of lighting after dark, and in turn;
  - Increased opportunity for economic activity after dark
  - Increased opportunity for education/study after dark
- Reduced consumption of kerosene and other fuels for lighting, with subsequent benefits;
  - social (improved health, reduced time spent collecting firewood),
  - economic (liquid fuels are expensive) and
  - environmental (reduced deforestation, localised pollution) benefits
- Reduced collection and use of firewood through electric cooking, and in turn;
  - Social (less time spent cooking and collecting firewood, with subsequent health, education and gender benefits)
  - Environmental (reduced deforestation and localised pollution)
  - Economic (more time available for economic activity)
- Access to electrical device that supports economic activity
- Access to communications devices and subsequent benefits;
  - Social (Health and Education system benefits, family connections),
  - Economic (communications supporting economic activity).

In general, the *potential* benefits of electrification increase with the range of electrical services that the programme mechanisms can support, and the quantity of electricity provided to recipients. Theoretically, this would mean that the range and extent of benefits afforded by stand-alone programmes would usually vary as follows;

National grid connection > local mini-grid > SHS > Solar Lamp

2.3 Objectives of RIDS-Nepal and ADB-Bhutan Programmes

The high level objectives for each of the RIDS-Nepal and ADB-Bhutan Programme are similar, and shown in together with specific programme objectives in Table 4 below.

Table 4 – High Level Objectives and Specific Programme Objectives

	RIDS-Nepal[ix]	ADB-Bhutan[x]
High Level Objectives	To improve peoples' overall quality and standard of life, through holistic, long-term, integrated rural community development programs. Special focus is given on the poor, marginalised and disadvantaged people and community groups in remote, difficult to reach mountain communities, concentrating on the Humla district.	Improve living standards and quality of life for rural populace and to stimulate economic growth within the rural populace. Help attain equity to rural populace - same level of opportunity and access to service for all citizens of Bhutan, and to combat urban drift. Support MDG and SAARC Goals toward; - Eradication of poverty and hunger - Integrate sustainable development and reverse loss of environmental resources - Retain acceptable level of forest cover - Retain acceptable level of water and soil quality - To Ensure Environment Sustainability, in particular Target 9 sub- indicators pertaining to energy per capita use and CO2 emissions
Specific Programme Objectives	To improve the overall living, health and hygiene conditions through relevant preventative measures such as awareness, education and implementation of context related holistic community development projects in objectives below.	To provide Rural electrification to 100% of the Bhutanese populace, with 88% supplied on National Grid (MEA/9), and 12 % through off-grid renewable energy supported solutions (MEA/12), by 2013.
	To implement the "Family of 4" concept, light, smokeless metal stove, pit latrine and drinking water, in entire villages and individual houses.	Within MEA/09: RURAL ELECTRIFICATION PROGRAMME Expanded coverage of rural electrification through grid supply and provision of grid electricity access for new and left-out/fill-in households.
	To provide energy services in the form of rural village electrification projects for light (through solar photovoltaic systems or pico-hydro power plant) in each house, and hot water through solar water heaters for community bathing centres.	Within MEA/12: DEVELOPMENT OF RENEWABLE ENERGY 3,582 off-grid houses electrified, 1000 SPV rehabilitated, 2 micro hydels installed, 112 houses electrified through micro hydels, 1 wind turbine installed for electricity generation, 1 biogas demonstration plant built
	To improve the food and nutrition availability and variety of high altitude mountain communities' through greenhouses, solar driers and nutrition programs.	

[ix] All Objectives information for RIDS-Nepal programme are taken from RIDS-Nepal website; http://www.rids-nepal.org/
[x] All Objectives information for ADB-Bhutan are taken from RGoB's 10th Five Year Plan

An initial observation for these objectives is that the RIDS-Nepal programme has simple statement of broad high level objective, but includes detailed programme specific objectives that are linked directly to intended impacts. In contrast, the ADB-Bhutan programme indicates specific impact areas within its high level objectives, but does not link these to the programme specific goals which are purely focussed on providing electrification to all of rural populace, through either grid, or off-grid solutions.

In regard to high level objectives, while both programmes focus primarily to improve the living standards and lives of the rural populace they address, the Bhutanese electrification programmes are also concerned with more specific address of equity issues between rural and urban populace, and with reducing the incidence of urban drift. This partially explains the ethos behind the streamlined approach – part of its goal is to provide same level of access for all as rapidly as possible, rather than seek to maximise benefits during implementation, which might cause significant delay in provision of access for all.

The high level objectives for electrification in Bhutan are expanded upon further in the Tenth Five Year Plan – addressing energy poverty is seen as a key agent helping to break the overall cycle of poverty. In particular, electrification is seen to support specific MDG and SDG (SAARC[xi] development goals), in particular through reducing dependency on fuelwood, so supporting reduced deforestation and alleviation of fuelwood collection time and cost.

The lack of linkage between ADB programme specific objectives and high level intent is stark when compared to RIDS-Nepal, and the Bhutanese approach for electrification at household level can be summed up as follows; access to electrical services directly addresses energy poverty, and associated benefits will automatically follow.

The RIDS-Nepal approach is more intent on focussing on end-objectives from programme deliverables, rather than the deliverables themselves. As a result the programme delivery has evolved over time, in order to best achieve intended benefits, within programme resourcing constraints.

[xi] South Asian Association for Regional Cooperation

3.0 Research Design

This research project is based on literature review of the intent and follow-up results for the RIDS-Nepal and ADB sponsored rural electrification programmes in Bhutan conducted during the 2000 – 2007 period. The literature review endeavours to understand the context of programme construction and delivery (section 2.1), the high level and specific programme objectives (section 2.3), and the results the programmes have achieved in regards to;

- fuel switching and improved energy services (section 4.1)
- associated benefits (section 4.2);
- sustainability of benefits (section 4.3).

These areas will be examined in regard to the specific focus questions enunciated in section 1.3.

The RIDS-Nepal programme reviewed include implementation of its Family of 4 and Family of 4 Plus programmes in the Humla district of Nepal, while the ADB sponsored programmes reviewed are the Sustainable Rural Electrification Programme (SREP), and the Rural Electrification Network Expansion Programme (RENEP), known as ADB-II and ADB-III.

Limited literature exists in regards to the results from these programmes, and consequently, the results and analysis in Sections 4.0 and 5.0 depend heavily on three main literature sources as listed in bibliography;

1) The ADB Evaluation Study of ADB – II and III programmes ("Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010");

2) Jason Mann's study on the impact of RIDS-Nepal SMS and solar lighting on respiratory ailments due to reduction of Indoor Air Pollution;

3) Gavin Naylor's study examining the impacts of RIDS-Nepal provision of Smokeless Metal Stoves within the Humla communities.

Despite the limited number of literature sources involved, the quality, transparency and hence usability of these sources is high, as they provide both raw and synthesized resulting impacts from implementation of the two programmes being compared in regard to the main overlap area of concern – impact of the programmes in regard to decrease of fuelwood dependency, and resulting benefits.

The ADB Evaluation Study provides quantified results and analysis across all impact areas for ADB-II and III, for extensive survey and measurement of households electrified during the course of ADB-II and III, and uses a counterfactual group of unelectrified households (in lieu of baseline data for the electrified group). Mann's research provides collation, and rigorous statistical analysis of RIDS-Nepal quantification of results compared to baseline data from its provision of SMS and solar lighting solutions to households in the Humla district, while Naylor's research is primarily based on his own survey work on impacts of RIDS-Nepal programme, with conclusions based on qualitative analyses.

While the study is based on review of available literature, in order to help better understand the context for programmes' delivery, and their intent and rationale in programme design and delivery the Author was also able to arrange, and privileged to meet with;

- Mr Alex Zahnd, founder of RIDS-Nepal Agency, and;
- Mr. Drukchu Dorji and Mr Norbu Tshering, who are Bhutan Power Corporation's General Managers for Rural Electrification and Resourcing; respectively.

The Author is also privileged to be a repeat visitor to the Himalayan region, and so has a firsthand appreciation of how dependant rural communities in this region are on traditional energy forms, and how vital access to improved energy services in such challenging climate and terrain is to improving their quality of life.

4.0 Results

Ultimately, the common delivery feature to both programmes is to support improved energy services, either through;

- provision of an energy service where none existed previously;
- fuel switching of an existing service to improve its performance, or;
- improvement in the safety, reliability, extent or efficiency of an existing energy service.

While the ADB-Bhutan electrification programme is focussed purely on improvements that are energy related, the RIDS-Nepal programme places energy services within a holistic suite of measures, such as provision of pit latrine and drinking water. These non-energy related services are not considered here, except where their provision has some impacts on when and how RIDS-Nepal seeks to provide the energy service related inclusions.

This section will focus initially on overall success in improving energy services within each programme, then considering the associated benefits, and how sustainable these benefits are likely to be.

4.1 To what extent is fuel switching or improved energy service realised within each programme?

RIDS – Nepal

The RIDS-Nepal holistic approach uses one primary element of fuel switching within its initial Family of 4 programme; provision of elementary electric lighting (WLED based, powered by solar or pico-hydro) to replace traditional lighting means. The replacement rate was found to be 100%, with Jharro stick[xii] lighting the predominant traditional lighting replaced.[46]

For cooking and heating, the RIDS-Nepal programme focuses on improving the energy service through increasing energy efficiency, and health and safety of the device. The primary mechanism to address this within the Family of 4 is replacement of open fireplace or chimneyless stoves with smokeless metal stoves, which is provided as second step to all participants in the Family of 4 programme delivery, with approximately 75% of the cost subsidised by the Programme.

The stove allows simultaneous cooking of all evening meal components, space heating and water boiling with smoke free results, and less fuelwood consumption. RIDS-Nepal estimates that it has installed ~4,500 SMS in 13 villages in the Humla district over the past decade.[47]

Results from Naylor's qualitative survey work revealed that all households used all of the functional components of the stove, and 75% reported using less fuelwood for cooking.[48] Limited quantitative analysis supported this finding: in analysis of RIDS-Nepal baseline versus follow-up survey results for Simikot, Naylor found that SMS reduced average daily fuelwood consumption from an average 15-30kg per day to 10kg per day for a 5 to 6 person household.

xii

Further elements within Family of 4 PLUS extensions programme to address improved energy services include greenhouse and solar dryer (using solar thermal to support nutrition objectives), communal hot water service (using solar thermal or pico-hydro power), and solar cooking.

Quantification of food quantity impacts of greenhouse and solar driers [enabling food production and storage to improve nutrition in non-spring/summer months] was not reviewed, however it is noted that RIDS-Nepal have aided the construction of 35 greenhouses, and 16 Solar driers in remote villages. These have provided the ability to grow vegetables for most of the year, and to increase quantity of dried foods necessary to improve nutrition in autumn and winter months.

Figure 3 – RIDS-Nepal prototype and test greenhouse at Simikot

Pictures of RIDS-Nepal prototype and test greenhouse at High Altitude Simikot Office (HASO) facility, located at over 3000m, where temperatures dip below freezing for over 199 days of the year.[xiii]

ADB-Bhutan

In contrast to RIDS-Nepal, the approach of the ADB programme in Bhutan is focussed purely on providing access to cheap electricity (government subsidised), with the expectation that fuel switching to electricity, and thence improved energy services, will follow automatically.

The Evaluation study reveals quantitative results for fuel switching for activities as a result of rural electrification carried out within ADB-II and ADB-III. Results selected to illustrate fuel switching success are reproduced from Appendix 8 of the Evaluation study, in Table 5 below. The figures shown in Table 5 are survey results in percentage of households surveyed, so it must be remembered that the un-electrified households are a counterfactual group, as proxy for baseline data: other confounding variables such as income were tested and considered so as to remove bias within ADB analysis, but may still impact on unprocessed results.

[xiii] Reproduced from RIDS-Nepal website, www.RIDS-Nepal.org, with kind thanks to RIDS-Nepal.

Table 5 - Adoption of energy services as a result of rural electrification[xiv]

Activity	Electrified households	Un-electrified households
Main source of lighting (%)		
Electricity	100	0.50
Wicked Lamp	0.00	84.63
Other	0.00	15.87
Main Source of Cooking (%)		
Electricity	76.99	0.76
Fuelwood	20.32	94.58
Other[a]	2.69	4.66
Primary cooking/heating Appliance ownership (%)		
Traditional stoves [without chimney]	79.06	89.55
Smokeless stoves or Bukhari[b]	*(3.68 / 21.93)* 25.61	*(3.15/18.51)* 21.66
Electric Stove	4.68	0.13
Ancillary cooking/heating appliance ownership (%)		
Rice Cooker	86.35	1.13
Electric Water Boiler	48.01	0.13
Electric or oil column heater	4.88	0.51
Communications appliance ownership (%)		
Mobile Phone	72.32	57.93
Radio/Transistor	55.29	64.99
Television	33.59	1.64
Fuel Switching measured (quantity)		
Yearly consumption of fuelwood (t)	2.21	2.87
Yearly consumption of kerosene (l)	16.18	53.39
Trees cut for fuelwood (no. per year)	1.40	1.62
Other domestic appliance ownership (%)		
Sewing machine	4.22	2.77
Electric fan	15.41	0.25
Refrigerator	13.34	0.13
Other characteristics (%)		
Tapped water – private	56.36	56.20
Tapped water - shared	28.76	27.46
Private Toilet	97.01	97.86

[a]includes LP Gas, Kerosene, animal dung and other traditional forms.

[b]Bukhari is a fuelwood based house or space heating system with smoke exhaust through chimney.

It is clear to see from the Evaluation Study survey results displayed in Table 5 that provision of access to electricity within ADB-II and ADB-III in Bhutan has led to electricity becoming a preferred fuel throughout these households. This achievement is not a guaranteed outcome of electrification programmes, as recipients need not only access to electricity, but must possess the ability to pay for electricity fittings and consumption, for electricity uptake to occur throughout target audience.

[xiv] Reproduced from Tables 8.2, 8.3 and 8.5 of Appendix 8 from the Evaluation Study: *Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life?* Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]

The Royal Government of Bhutan has sought to ensure these outcomes for all of its electrification programmes, including those run with ADB, by heavily subsidising electricity power prices through electricity export earnings, to make consumption affordable, and by distribution of electrification kits to poorest households, who may otherwise be unable to afford internal wiring required for lighting and power points.

Consequently, the survey results show that electricity is universally adopted for provision of lighting, displacing kerosene consumption from wicked lamps and other traditional forms, and most likely the small number of dry cell battery supported lighting that is used in unelectrified households. Electricity has also supported increase in usage of communications devices [most especially televisions], and in fuel switching for cooking purposes.

The survey results suggest that electricity has become the dominant fuel for cooking purposes for over ¾ of electrified households surveyed, with the majority of remainder still reliant primarily on fuelwood. This is a marked fuel switch choice compared to the un-electrified counterfactual group, where almost 95% of households were reliant on fuelwood for cooking purpose.

More detailed examination reveals that electricity has supported widespread uptake of rice cookers (86%), and electric water boiling[xv] (48%), but relatively small uptake of electric stove (~5%). As cooking and heating utility is mixed in Bhutan residence, with both functions often supplied by the same device, the cooking and heating fuel switch must be looked at in parallel.

It is clear from the results that traditional stoves, without chimney, continue to be a central appliance for heating and cooking purpose, with 79% of electrified households continuing to use this appliance. Over ¼ of electrified households reported use of smokeless stove or Bhukari, while less than 5% owned electric space heating devices.

From this it appears that the actual fuel switch for cooking is likely to be restricted primarily to rice cooking and boiling water for hot drink and cooking purpose, while very little fuel switching has occurred in regards to adoption of electricity for space heating purposes. Anecdotally, it is evident that nearly all domestic cooking remains traditional, and is carried out via wood-fired stove.

This raises the question as to whether the survey result - that 77% of electrified households described electricity as the primary support for cooking - reflects the added convenience of electric cooking devices, rather than actual fuel load. Some inference can be drawn as to whether the fuel switching to electricity for cooking and heating has been material – rather than primarily displacing ancillary heat from stoves that burn the same quantity of fuel regardless – can be made from looking at the fuelwood consumption reported.

The survey results show that electrified households estimated use of 2.2tonnes of fuelwood per annum, and cut an average of 1.40 trees for fuelwood, while unelectrified households used 2.87tonnes per annum and cut an average of 1.62 trees for fuelwood. Taking these consumptions at face value[xvi], and allowing that relative comparison can be made as estimation techniques were the

[xv] electric coil, jug, kettle or urn

[xvi] Other estimates suggest fuelwood consumption in Bhutan is ~1.1-1.5tonnes per person, suggesting 6-7tonnes consumption per household as a more typical figure for rural households that are either electrified or unelectrified.

same for all surveyed households, this suggests an average reduction of up to ~20% in fuelwood consumed in electrified households.

This suggests that electric cooking has had some impact on reducing fuelwood consumption, and benefits extend beyond solely providing convenience. Nevertheless, it is clear that electrified households remain heavily reliant on fuelwood for cooking, and almost entirely reliant on fuelwood for heating purposes.

Electrification in ADB-II & III has also had measurable impact in supporting greater access to communications and entertainment devices in households, with;

1] Mobile phone ownership rate over 25% higher in electrified households,

2] Television ownership rate over 33% higher in electrified households.

While no quantification of dry cell battery use can be found for electrified households, it is likely that electrification programmes have supported switching from dry cell battery to mains or SHS power to support radio, transistor and mobile phone charging, allowing easier usage of these devices. It has also supported uptake of television, and vastly improved communications access for community facilities and private enterprise, that are further explored in section 4.2.

Summary Comparison and Evaluation of Results as to extent of fuel switching / improved energy service

A net evaluation of the success of each program with respect to extent of fuel switch or improvement of energy service (as discussed in section 4.1) is shown in Table 6 below;

Table 6 - Summary of Fuel Switch / Improved Energy Service Results

Fuel switch/Improvement to energy service	RIDS-Nepal	ADB – Bhutan II & III
Lighting	High – 100% switch Lighting quality low-medium, but massive improvement on prior lighting service	V.High - 100% Lighting quality very high
Cooking **&** **Heating**	V. High 100% subsidised provision of smokeless metal stove, displacing chimneyless stove or open fireplace – massive improvement of energy service for both cooking and heating, through significant gain to wood burning efficiency and elimination of IAP	Medium - High Significant use of electricity for ancillary cooking device, but very low (5%) displacement of wood stove for primary cooking device Low Small (5%) uptake of electricity for ancillary heating device only
Hot Water	Medium All SMS include 9Litre hot water tank, that can entirely provide all beverage and cooking needs, and also with hand/face washing capability	Low ~50% uptake of small scale water boiling, primarily 1-2L size to assist with beverage/cooking, less hygiene purpose
Displaced Fuelwood	Medium-High 1/3-2/3 measured reduction in fuelwood consumption depending on switch from chimneyless stove/open fireplace	Low Significant, but modest [10-20%] reduction in fuelwood consumption as a result of access to electricity
Communications	Low Improved access to mobile phone charging	High Large increase in access to telephony, television, computing and internet

4.2 To what extent are associated benefits realised as a result of each programme?

While specific programme delivery goals are very different, both RIDS-Nepal and ADB-Bhutan programmes seek similar high level objectives – to improve the quality of life of rural populace through providing access to improved / modern energy services. The programme objectives are also ultimately expected to provide benefits in specific impact areas that are in common between each programme.

The areas examined here include benefits to households related to fuel switching or provision of improved energy service, namely positive impacts in health and hygiene, environmental (specifically related to reduced fuelwood consumption), socio-economic (freeing up education and labour time), and community rather than household focussed benefits.

RIDS – Nepal

The RIDS-Nepal programme has a strong focus of improving health and hygiene, indeed all of its core elements are designed primarily for improvement of health and hygiene, but holistically coordinated with other beneficial impacts, such as environmental, social and economic.

The first implemented element of Family of 4 is the provision of pit latrine to households. RIDS-Nepal identifies this as the most impactful of its programme elements, as it provides critical health benefits in reducing incidence of parasitic worms, and faecal contamination causes of gastro-intestinal and other diseases. No quantification of the beneficial impacts resulting from RIDS-Nepal implementation was found in literature survey, but the importance of sanitation are well understood and widely acknowledged.[49]

The second and third elements of the Family of 4 focus on providing solutions for cooking/heating and lighting to enable a smoke free household. These are targeted primarily at improving health of household residents and quality of indoor living conditions, through provision of smoke-free indoor environment, and vastly improved indoor lighting.

In 2008/9, Naylor conducted qualitative survey based research on the positive impacts of the SMS on improving well-being and livelihoods within recipient Humla communities. He evaluated that the SMS had marked positive health and hygiene impacts, including;

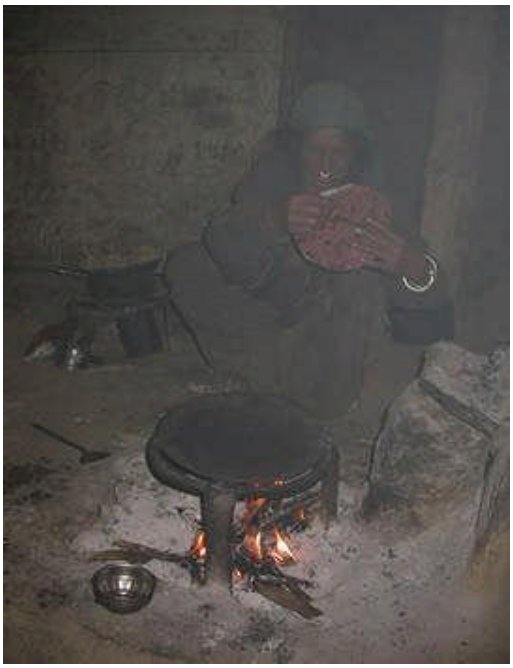
- Marked improvement in indoor air quality, (both in survey response, and measured particulate and carbon monoxide (CO) by RIDS-Nepal in controlled simulation)
- Marked improvement (reduction) in reported incidence of respiratory problems
- Marked improvement (reduction) in reported incidence of eye problems
- Improvement in access to hygiene through increased access to hot water [the RIDS-Nepal SMS has a 9 litre hot water tank].

In 2009, Mann conducted rigorous statistical analyses of RIDS-Nepal before and after survey questionnaire of 265 households (1601 individuals) who received SMS and solar lighting, to evaluate the positive impact of smoke free environment on respiratory illness achieved though RIDS-Nepal

intervention.[50] Once screened for confounding factors, such as smoking and seasonality, prevalence rates of each were still found to have dropped significantly.

The follow-up survey was carried out on average 1 year after implementation, suggesting that benefits in the higher age groups will increase further over time.[51] Overall, Mann's findings clearly illustrate marked and strong reduction in both respiratory ailments and eye disease as a result of provision of SMS and lighting by RIDS-Nepal.

Figure 4 – Cooking (and heating) with open fire, and with smokeless metal stove



The largest transformation in achieving smoke free is in moving from open fire, or chimneyless stove, to SMS.[xvii]

In addition to positive health and hygiene impacts, Naylor found strong benefits in regards to reduced fuelwood consumption, and associated with this reduced deforestation and labour effort spent gathering firewood. Over 75% of respondents to his survey work cited strong decrease in time spent collecting firewood, and he was able to identify an average 1/3 – 2/3 reduction in collected firewood quantities for an average households of 5-6 people as result of installation of SMS.[52]

The fourth element of Family of 4 is provision of filtered drinking water to Humla communities. No quantitative assessment of associated health benefits for Humla was found for this, however, as with pit latrine solution, the anticipated reduction of cholera and other water born diseases is well documented.[53]

RIDS-Nepals' Family of 4 PLUS programme includes further elements focussed at providing further benefit to health and hygiene in particular, and are delivered more through community rather than household based implementation.[54] These include;

- communal bathing house supported by customised high altitude solar hot water system;
- greenhouse to support vegetable production over more months of the year; and
- solar food drier to aid food storage over non-production months.

[xvii] Reproduced from RIDS-Nepal website, www.RIDS-Nepal.org, with kind thanks to RIDS-Nepal.

No analysis of benefits to Humla communities post implementation of Family of 4 PLUS elements was found in literature survey, and their implementation may not be widespread enough yet to have warranted this focus. RIDS-Nepal has identified significant potential benefits to hygiene and nutrition, and is in the process of assessing achieved benefits.

ADB-Bhutan

Health and hygiene benefits are pivotal amongst the associated quality of life benefits anticipated to result from rural electrification programmes in Bhutan.[55,56] At the household level, this is anticipated to arise chiefly from reduced consumption of wood and thence indoor air pollution, kerosene and other traditional fuels for lighting, heating and cooking.

The ADB's Evaluation study of ADB II and III examined electrifications' impact on health risks associated with exposure indoor air pollution by examining the difference in incidence of these risks between households electrified in the course of ADB–II and III, with a counterfactual group of unelectrified households. The health risks examined included incidences of cough, chronic respiratory ailments, eye irritation and headache.

The Study found a significant decrease in incidence of eye irritation (~13%) as a result of electrification, and still smaller impacts associated with reduction of cough and headache. The Study was surprised to find no statistically significant decrease in incidence of respiratory related illness between electrified and unelectrified households.[57]

The Evaluation Study's findings suggest that more considerable positive health impacts were achieved through resulting improvements to community health facilities, and access to health information and education. Although impacts were not quantified, electrification has provided lighting, computing and communication within clinics, hospitals and homes.[58] This in turn has provided clinics with longer effective opening hours and access to specialist medical resource/advice through phone and internet, and improved availability of lighting and hot water to facilitate both clinic and home birthing.[xviii]

Reducing fuelwood consumption was another highly anticipated benefit for rural electrification programmes in Bhutan. The Evaluation Study found that 91% of ADB electrified households used fuelwood for cooking and heating, compared to 96% for unelectrified households; with the vast majority of households remaining dependant of fuelwood for heating, cooking and hot water for bathing purpose. Modest reductions in cutting trees for fuelwood were found, with electrified households reporting an average of 1.40 trees cut for fuelwood compared with 1.62 trees cut by non-electrified households.

The Evaluation Study findings are confusing here, as it suggests that the decrease in fuelwood consumption is smaller when collected fallen-wood is considered in addition to tree cutting, but reports a total average decrease from 2.87 to 2.21 tonnes of fuelwood annual consumption as a

[xviii] The study noted that home birthing was still preferred for reasons of culture, difficulty in road/travel access to birthing in hospital/clinic, but that that this had been greatly facilitated through access to hot water and improved lighting quality as a result of electrification.

result of electrification. On the basis of the Study's raw and treated results, it appears that an approximate 10-20% reduction in fuelwood consumption is observed.

This scale of reduction is correlated by findings on time saved for fuelwood collection. Inhabitants of houses electrified during ADB-II and III spent 10-15% less time on collecting fuelwood than the unelectrified counterfactual. [59]The Evaluation Study was surprised to find that while electrified households consumed on average less fuelwood overall, they burnt through their fuel more quickly, with a fuelwood bundle lasting on average 2.48 days in summer and 1.68 days in winter, compared to 2.96 days in summer and 2.09 days in winter in the unelectrified counterfactual group.[60]

Reduced time spent on collecting firewood and access to electric lighting has afforded significant positive impacts on education and economic activities. The freed up time and ability to continue study or work after dark was measured through an increase of 25% in average study time per day spent by schoolchildren in electrified households, and survey response suggesting resulting improved ability for microenterprise.

While not quantified, the Study found that significantly increased access increase to communications devices; primarily telephones and television within homes, and computers/on-line resources within schools, has provided information and tools to support education and economic activities (such as business and microenterprise). Benefits to education extended beyond enabling technologies' direct impacts – it was found that electrified villages were better able to recruit and retain more qualified and experienced teachers than unelectrified villages.

The overall impact of the ADB rural electrification programmes for communities is far greater than shown in the evaluation study, when gains in community and commercial infrastructure are considered in addition to residential impacts. Beyond benefits to schools, hospitals and clinics noted above, electrification in ADB-II and III have supported improved facilities in hotels, shops, restaurants, regional administration and temples. In particular, electrification has supported communications and quality lighting for all of these entities.

Summary Comparison and Evaluation of Results related to Associated Benefits

A net evaluation of the success of each program with respect to associated benefits as discussed in section 4.2 is shown in Table 7 below;

Table 7 - Summary of Benefits Associated to Fuel Switch / Improved Energy Services

Benefits Associated to Fuel Switch/Improved Energy Service	RIDS-Nepal	ADB – Bhutan II & III
Health & Hygiene – Household Level	V. High** Massive improvement to IAP as a result of SMS intervention has had large measureable impact on respiratory illness, eye irritation, headache, plus modest improvement due to 9Litre hot water tank on stove	Low Impact has been low within households, with minor improvement to eye irritation, most likely attributed to less interaction with stove during cooking
Health & Hygiene – Community Level	Medium** Nutrition is strongly addressed in Family of 4+ recipient communities, through provision of greenhouse and	**V. High** Through vastly improved health services and access to health information through improved

	solar driers. Community bathing centres have had marked impact on hygiene, however few of these installed.	communications. Benefits are shared between preventative and curative health treatment, but skewed to remedial.
Reduced Fuelwood Consumption	Medium-High 1/3-2/3 measured reduction in fuelwood consumption depending on switch from chimneyless stove/open fireplace	Low Significant, but modest [10-20%] reduction in fuelwood consumption as a result of access to electricity
Related Environmental Benefits	Medium-High Based on reduced fuelwood consumption [nearly all wood is cut], assumed slowing of deforestation rate of up to 50% for localities where RIDS-Nepal has been fully deployed.	Low Reported reduction from 1.62 to 1.40 trees cut for fuelwood per annum measured [12-13% reduction]
Reduced Labour time on HH chores / increased opportunity for education or earning opportunity	Medium No quantified measurement of time savings from reduced collection of firewood, but infer significantly reduced from above results. Access to lighting is first lighting available to provide adequate lighting to support study/microenterprise after dark	Medium Through measured savings of 10-15% less time collecting firewood, plus provision of adequate lighting after dark, measured increase of 25% time available for study.

***Note, the RIDS-Nepal Intervention has had further very high improvements to health and hygiene at both HH and community level through non-energy related interventions including pit latrine, filtered drinking water, and education programmes.*

4.3 How sustainable are the programmes, and their realisation of benefits?

Sustainability of programmes, and delivered benefits are crucial end-points to evaluation of success of programmes. Success in delivery of roll-out and realisation of benefits are meaningless if these gains are not sustained – perhaps it is still crueller for an impoverished community to have witnessed improvements to quality of life through an aid programme and then lose these, than to have never experienced these improvements at all. Electrification and lighting aid implementation efforts in the Himalayas, and particularly within Nepal, are littered with such examples.

The two programmes examined here have very different challenges to providing sustainable implementation, both in regards to continued funding resourcing/internal government support, and community ability to self-sustain improvements. Both have entirely different design parameters that are governed primarily in the endeavour to deliver sustainable benefits.

RIDS – Nepal

Within its programme, RIDS-Nepal faces unbelievable challenge to ensure that the benefits it brings are on-going and sustainable; even within the context of remote, impoverished Himalayan communities, the Humla region it has chosen to operate within can be fairly described as amongst the very remotest and near poorest within this communities. Moreover, RIDS-Nepal is aware that the funding and support assistance it provides will not be on-going: once initial implementation is complete, whatever systems are established must be able to be self sustained by the local communities they are implemented within.

Accordingly, the Family of 4 and Family of 4 PLUS programmes are designed with the following tenets;

- achieving and maximising impacts through provision of energy services with ultra low-grade energy demand, so that the community can afford to service running costs,
- focus on simplicity within replacement energy services
- focus on community appreciation of collective benefits gained by all programme components
- engaging community recipients in the construction/implementation and maintenance elements of programme components.

Within initial roll-out of Family of 4, delivery is staged to ensure most impactful components are implemented first, so that benefits are easily identified by the recipients, and the implementation is valued. Likewise, elements with synergistic or combined impacts – such as focus on smoke free homes requiring both provision of smokeless stove and improved lighting solution – are carried out in sequence and/or together, to help households maximise and identify the positive impact.

In order to engage initial acceptance and be valued, each component is carefully designed to fit the Humla community and maximise benefits. For example, the SMS solution was designed and engineered to optimise combustion efficiency [thus maximising fuelwood reduction benefits], eliminate this source of smoke, and to suit Nepalese cooking style, so as to ensure acceptance by the target audience.

Local community support is used to build, install and implement systems, and recipient communities are fully trained in systems operation and maintenance. These installed systems are designed to operate on very low grade power, in order to keep replacement components as affordable as possible. For example, lighting systems installed utilise WLED lighting, so that globe and battery replacement costs for solar based systems are minimised and centralised systems (such as central community based PV Array or pico-hydro units can be sized far smaller, with more replaceable and affordable componentry.[xix]

Learning from its early project attempts, in providing implementation that would prove hard to sustain, RIDS-Nepal has taken further effort to improve sustainability by establishing local cottage industries within Nepal based around manufacture of RIDS-Nepal designed smokeless metal stove, and of WLED clusters. These efforts have brought down the costs of SMS and WLED and had marked impact on initial affordability, and affordability of replacement.

By establishing these industries, the Programme has had significant reach beyond its own confines, with SMS proving popular in Nepal, with this benefit available far beyond the Humla RIDS-Nepal beneficiaries. This is a best practice example, where a programme's success has led to organic, non-programme sponsored growth, similar to the growth and diffusion of the SHS with micro-credit facility programme approach developed by Grameen Shakti in Bangladesh.[61]

[xix] A good example of the last instance is the move away from initial RIDS-Nepal projects with >10kW sized microhydro/PV toward tiny.

Despite all these efforts, RIDS-Nepal acknowledges that challenge will still exist for beneficiary communities to retain and continue trapping these benefits, particularly in some Family of 4 PLUS projects, where external components, such as small generators, PV electrical components or solar hot water system components will require replacement in the future.

Nevertheless, RIDS-Nepal efforts appear to have paid off – Naylor's qualitative survey work found that benefits and impacts were still high, acknowledged, valued and *sustained* by local communities well after programme provision.[62] This is in stark contrast to the majority of off-grid electrification programmes in Nepal, which provide high cost equipment, and fall over as soon as battery or other component replacement is required.[63]

ADB-Bhutan

The ADB electrification programmes in Bhutan face an entirely different set of challenges to those of the RIDS-Nepal programme. With context of stable proactive government, and continued generous donor support, the ambition and ability of all streamlined electrification programmes in Bhutan are of a much higher scale, and are focussed on providing significantly access to power than RIDS-Nepal programme.

The ability to co-fund and entice funding support or commercial investment for initial massive capital requirements to provide electricity to the entire rural populace is based on successful development of hydropower resources and resultant export earnings. The primary challenge is to provide on-going affordable power to the urban and rural populace, where provision to the remote proportion in particular, is heavily subsidised, whilst ably servicing soft and hard loans for hydro and transmission infrastructure.

Given the small scale of Bhutan's potential domestic residential power demand over the short-medium term, compared to its power generation capacity and power export revenue, there is little doubt that over a 5-10 year time period, while expensive transmission and off-grid infrastructure is relatively new, this is a sustainable model. In accordance with this, the ADB Evaluation Study deemed that ADB-II and III programmes and approach were "*likely to be sustainable*" providing continued government commitment to sustaining current power pricing subsidies occurs, but notes that this continuing subsidy is likely to come under pressure over the longer term.[64]

The Evaluation Study also notes that the subsidized electricity price is the lowest in Asia, thanks to a generous lifeline block of 100kWh per month as per August 2010 available at 0.85Nu (~1.8 US cents/kWh) to residential households, with decreased subsidy on higher usage.[65] Despite this affordability, and high surveyed willingness to pay more, electricity use was mostly confined to lighting, rice cooking and water boiling, with average use well under the lifeline block quantity.

Significantly higher residential consumptions of electricity might pressure the sustainability of either the continued subsidy level, or the ability of consumers to pay. The existing barrier to higher consumption and fuel switching to electricity is likely to be centred on affordability of electrical devices, as much as affordability of tariff beyond the lifeline block. The Study also found that no evidence of promotion or adoption of energy efficient products existed within the electrified rural populace.[66]

While the current subsidy level and overall power generation export/internal supply model in Bhutan can clearly be sustained for the foreseeable future, the real cost of maintaining one of the most terrain-challenged transmission grids in the world may prove beyond current estimations. Moreover, if average residential electricity services increase as intended, resulting power consumption rise is likely to place pressure on either the subsidy level, or affordability to consumers.

Summary Comparison and Evaluation of Results as to the Sustainability of Programmes and realisation of benefits

A net evaluation of the success of each program with respect to sustainability aspects discussed in section 4.3 is shown in Table 8 below;

Table 8 - Summary of Programme Sustainability

Programme Sustainability	RIDS-Nepal*	ADB – Bhutan II & III
Design features to promote programme sustainability	• Programme endeavours to maximise benefits through holistic implementation, while using the lowest energy quantity possible so reducing up-front and programme maintenance costs. • Programme has included development of local cottage industry to reduce costs. • Programme seeks to involve recipient community in building and installation, so as to maximise buy-in and understanding.	• Programme based on highly subsidised provision, including low minimum block tariff Underlying subsidy is highly sustainable, as it is based on power export revenue earnings, and power export will continue to dominate domestic power consumption for the foreseeable future.
Net Economic and Technical sustainability	Short term – High Medium Term – High Long Term – High Expansion of scope – Low-medium	Short term – V. High Medium Term – V. High Long Term – Medium** Expansion of scope – V. High
Community engagement and ownership of improvements	High Survey has shown high appreciation and acknowledgement of benefits, most of infrastructure has high community involvement in installation and ability to maintain.	Medium-High Evaluation Study showed high appreciation of benefits of electricity already utilised, and willingness to pay for existing levels of power consumption under current subsidies. However, concern/low willingness to pay for higher levels of electricity consumption was revealed in the evaluation study.
Environment	High All aspects of programme are designed with environmental consideration in mind [generation and end-use devices are low impact] Programme has strong net impact on slowing de-forestation.	Medium-High Underpinning hydro development does incur some environmental change/damage to habitat etc. Some aspects of programmes [eg: electrical waste, especially CFL] may have significant long term impacts.
Social	Medium – High Social impacts are very high due to positive impacts on health, nutrition and hygiene and quality of life, made primarily at household rather than community level. Energy could be used to support more community-level activities.	V. High The community level benefits, in regards to education, health, public and private enterprise [particularly hospitality, retail and tourism] are as significant as impacts at household level.

*[Programme has been designed in context of widespread peer programme failure (sustainability-wise) in Nepal].
**While programme has strong ability to financially support itself over short-medium term, the long term renewal costs of infrastructure will be very high. While financially within scope of RGoB given power export earnings, high costs of transmission infrastructure will deprive the government with respect to other spending priorities.

5.0 Analysis

The results in section 4.0 provide a window into how successful the programmes have been in reaching both their specific objectives, as well as their high level objectives, as outlined in section 2.3. These also allow consideration as to how differently the programmes have been designed to meet markedly different resources and constraints, in order to meet common high level objectives and impacts, across similar target audiences.

In regard to specific objectives, the uptake of fuel switching and improved energy services reveals that both programmes have had extremely high level of success in regards to lighting. This is unsurprising, as mechanisms within both programmes - heavily subsidised provision of lighting systems in RIDS-Nepal, and free distribution of house wiring kits to poorest households in ADB-Bhutan - have been structured to ensure that access to electrical lighting exists for all recipients within each programme.

The quality of lighting achieved was not quantified for each programme, and varies to suit the economic environment in which each programme, and individual programme components, are delivered. In general, the ADB-Bhutan programme supports higher power consumption, and consequently higher quality lighting, which is primarily incandescent and compact fluorescent based. RIDS-Nepal provides far lower electrical energy quantity, and so utilises WLED lighting technology, in order to provide adequate lighting at far lower cost to consumer.

More importantly, both programmes provide a marked improvement in energy supported lighting services than was previously available – either displacing far poorer quality lighting means, such as kerosene, candle and Jharro stick, or providing lighting where no lighting at all had previously been available.

The net impact of each programme is resultantly very high in this area, with lighting supporting greater opportunity for education and work after dark, and considerable improvement to quality of life. This has been quantified in the ADB sponsored programmes with direct observable increase in average daily study time for schoolchildren of 25%, and in RIDS-Nepal survey results showing the lighting solution is highly valued by recipients.

In regards to health impacts related to the lighting improvement, both programmes have quantified benefits to eye irritation, but it is likely that RIDS-Nepal has extracted far more of the potential health benefit from a more modest lighting solution, by delivering its lighting solution in concert with overall focus on a smoke-free environment. The benefits of improved indoor air quality due to improved lighting systems in the ADB-II and III are nearly invisible in the context of continued high indoor air pollution resulting from chimneyless stoves.

Improvements to energy services for cooking and heating vary in both design and result between the programmes. The ADB-Bhutan programme has had widespread impact on uptake of auxiliary cooking appliances, in particular rice cookers and hot water boiling. These are significant improvements, but households benefiting from the programme still rely primarily on cooking stove as their main cooking device, with fewer than five per cent having switched to an electric stove for cooking.

The programme has had a similar or even lesser result for heating, with less than five percent of households having ownership of an electric heating appliance. As stoves are frequently used as the primary means for both cooking and heating, it is difficult for electricity to significantly displace wood fired stoves for these tasks. To replace either function [and therefore make more significant in-roads into displacing quantity of wood burned], cooking and heating appliances have to be affordable to households, and electricity must be cheap enough to run these appliances.

As such, the ADB-Bhutan programme has been able to displace approximately 10-20% of average household consumption of fuelwood for net cooking/heating purposes, through uptake of electric auxiliary cooking and boiling water, but will struggle to make further in-roads to reduce average household fuel-wood consumption.

This was identified in ADB evaluation study, which recommended tariffs be placed on collection of fuelwood, in order to realise significant impact on reducing fuelwood consumption.[67] Without this or other significant complimentary policy, households are likely to remain largely dependent on stoves for heating purposes. Alarmingly, nearly 80% of households within ADB-II and III identified at least partial, if not primary reliance on chimneyless stoves, and fewer than 30% having any access at all to smoke-free stove or Bhukari.

In contrast to the ADB approach, RIDS-Nepal has aimed to provide improved efficiency and smoke-free stoves, rather than electric support for cooking and heating. This approach is partly born of necessity: the programme cannot provide the scale of power required to support significant electrical load, nor could the participants afford these devices or electricity consumption, or be willing to abandon traditional cooking means.

Provision of smoke-free stove (75% costs of which are subsidised by RIDS-Nepal) to all households in a participating village is the second stage of the Family of 4 programme. This means that all households have witnessed impacts related to reduced fuelwood consumption and improved health. RIDS-Nepal have laboratory and field tested the smokeless metal stove, and found it to be up to 50% more efficient than the open fireplace and traditional chimneyless stoves being replaced.

This is consistent with the qualitative findings from Naylor[68] that indicated average reduction from 1/3 to 2/3 the amount of fuelwood required for cooking and heating within a 5-6 person household, resulting from provision of SMS. Perhaps more importantly, Mann was able to establish significant and causal reduction in incidences of all respiratory ailments and eye diseases causally related to indoor air pollution.

In contrast, evaluation of ADB II and III was unable to uncover any measurable or anecdotal reduction in respiratory ailments between electrified and unelectrified households. This is unsurprising, given that the extent of fuel switching is not likely to have had significant impact on indoor air quality with a very high proportion of electrified households still dependant on non-flued wood-fired combustion stoves.

Displacement of fuelwood through ADB II and III has led to measurable decrease in eye related ailments, and this is likely due to the increase in auxiliary electric appliances for cooking (rice cookers and electric kettle/urn), as cooking involves more closer interaction with chimneyless stoves. It has also resulted in observable reduction in time spent collecting firewood (estimated at 10-15%

reduction). Both these reductions are significant, but of far lower magnitude than the impacts achieved in the RIDS-Nepal programme.

The holistic approach of the RIDS-Nepal programme in this regard is likely to have achieved far more significant impacts within its target audience in regards to reduced fuelwood consumption and providing a smoke-free environment than the far more highly resourced ADB-Bhutan programme, within its target audience. This has been achieved as the Programme has kept these ultimate goals in mind throughout its delivery, whereas the streamlined electrification approach has focussed entirely on provision of electricity, and assumed that associated benefits to households would automatically follow.

This is different to other social impacts delivered at community rather than households level, particularly in regard to health and education benefits. In these areas, strong complementary policy delivered through other government agencies [education, health, telecommunications] has ensured that the ADB-Bhutan's approach has had significantly greater impact through other electricity supported energy services, namely vast improvements to community medical, education and communications infrastructure and resources.

In contrast, the RIDS-Nepal community level energy service interventions in Family of 4 Plus deliver significant benefits, but not as significant as the preliminary Family of 4 targeted at household level delivery. This perhaps brings into focus the difficulty of trying to achieve large impacts in community based delivery through energy services run of very low amounts of energy. RIDS-Nepal is very clever and inventive here in order to combat this – it targets nutrition through greenhouse and solar dryer technologies, and hygiene through centralised solar or pico-hydro based water heating – continuing to utilise the most available local renewable energy resources.

This also highlights a key difference between streamlined electrification approach and the holistic delivery approach of RIDS-Nepal. Whether the energy service related interventions are targeted at household level or community level, within the streamlined approach the areas extracting the most out of the potential benefits are those where other government agencies or end-users were waiting for electrical connection with specific goals in mind (such as schools waiting for higher electrical and communication services so they could use computers/internet), whereas the holistic approach is more based around identifying synergistic interventions.

Both programmes have retained strong deliberate design intent that the benefits they bring are ongoing and sustainable. The ADB-Bhutan programme provides far higher power to recipient households, in both grid and off-grid provision, but has intent that this power will continue to be subsidised through ongoing electricity export revenue. Given the still greater challenges and limitations it faces, RIDS-Nepal has had to consider how its benefits will be sustained with a still higher degree of sophistication.

Results have shown that the benefits realised through ADB-II and III are likely to be sustained and to potentially increase over time. These programmes have been designed to fit as key components within an overarching, highly coordinated electrification programme in Bhutan, with careful and considered development of hydro generation and power export market to India to sustainably support and underpin rapid electrification for the entire rural populace.

More prudently, even if the subsidy/affordability level for domestic power is sustainable, it is likely that energy efficiency or consideration of alternate energy services could lower this cost burden, freeing up government funds or disposable income for rural populace. Other sustainability aspects need also to be considered, for instance the environmental disposal considerations for compact fluorescent globes, and safety considerations in providing access to high voltage power supply to households with no prior experience with mains electricity.

An example of the dangers that accompany new provision of mains electricity is shown in Figure 5 below. The obvious benefits in using electricity rather than fuelwood to heat and boil water are well recognised by households, however uptake of water heating devices by ADB-II and III households are almost entirely limited to small volume heating (kettle, urn, small immersion coil), for reasons of availability and affordability – wood is still the primary fuel for heating water on a volume basis.

Alarmingly, the demand for more substantial electric water heating to allow bathing in cold climate, has led to home-made immersion devices, such as shown in Figure 5b. This device is preferred in some of the colder regions, such as Bumthang, where hot water is essential for adequate hygiene purposes for much of the year.

This device is placed directly in a Bhutanese bath, and turned on – if the user touches the water in order to test water temperature, they are likely to receive a fatal electric shock. Despite the acknowledged danger, such devices have begun to proliferate, as they are able to heat far more volume, and more swiftly than the safe commercial device shown in Figure 5a. This is an unintended, unsafe and inherently unsustainable means of fuel switching from wood to electricity.

Figure 5 - Unsafe and Safe Hot Water Heating in rural Bhutan[xx]

2a: Homemade hot water immersion heater – highly dangerous ►

2b: Immersion heater product retailed in Bhutan – safe but slow/limited volume heating ability
▼

[xx] Photographs taken by Author in Jakkar Valley, Bumthang, Central Bhutan

The RIDS-Nepal approach to supply of hot water to improve hygiene may provide alternate means for the RGoB towards tackling this issue. Given that electrical power available within programmes is more than sufficient, but availability and expense of bulk hot water heating device is the central barrier, the RGoB could consider establishing more village or gewog-based[xxi] bathing house facilities using electric hot water supply, to avert this dangerous instance, and so support hygiene and health prerogatives. Alternately, it could also consider establishing internal industry for manufacture of safe hot water devices, to lower costs, and support this and greater uptake by private households.

The RIDS-Nepal approach is designed to be sustainable and fit its peculiar context of delivery. As seen in section 2.0, it operates in a country where failed electrification and lighting programmes are myriad and predominant, and where;

- community ability to pay for improved energy services is very low,
- government subsidy is not available, and
- funding support is at a far lower scale per capita than the ADB funding for rural electrification in Bhutan

Accordingly, the programme has evolved to focus on using low amounts of energy and solutions with less costly maintenance towards achieving the same ends, so as to be affordable and sustainable.

In addition to this, great effort has been taken not only to train end-users with equipment, but also to involve them in construction/installation of equipment, such as pit latrine, drinking water, pico-hydro, greenhouse and solar dryer. Where this is not possible, RIDS-Nepal has sought to establish local cottage industries to deliver the more specialised equipment (smokeless metal stove, WLED lighting, solar hot water system).

[xxi] A gewog is a group of villages

6.0 Conclusion and Findings

Both the RIDS-Nepal Family of 4/Family of 4 Plus programme and ADB-Bhutan rural electrification programme have been appropriately and effectively designed to meet the needs of their target audience, within the abilities and constraints of the delivering agencies, and context of government and funding support.

The ADB-Bhutan programme has far more resource to draw upon than the RIDS-Nepal programme, and correspondingly has far higher ambitions in regard to quantity of power delivered to rural population, and in terms of reach. As it is an integral component operating within RGoB firm target for 100% Rural Electrification as rapidly as possible, its objectives align with this target – to maximise reach in short timeframes so as to achieve access to electricity for all by 2013 – which in turn demands a streamlined electrification approach.

Furthermore, it fits within a cohesive overall government energy planning framework based on hydropower development and export, and so can plan to offer domestic electricity with significant in-built subsidy on a long term basis. The Programme has delivered significant and immediate gains in regards to fuel switching and energy services, with strong positive impact on the lives of programme recipients.

Despite this, it is clear that in maximising reach and speed of roll-out, the potential benefits of providing improved energy services are far from maximised, and will require further policy and programmes to achieve. In some respects, the rush to provide immediate significant impacts to all rural Bhutanese as rapidly as possible has led the goal of electrification becoming the overall focus, whilst the end-benefits that improving energy services should target at household level have been overlooked.

This is an all-of-government issue to contend with – the BPC is acquitting its responsibilities for developing all aspects of power infrastructure admirably. Potential benefits to rural households need to be considered by other areas of government [such as health, forestry] as well. Excellent policy co-ordination between RGoB agencies has occurred in this area already with respect to community delivered infrastructure [schools, medical facilities, communications and roads] – it needs this same effort targeted at household level.

Contrastingly, the RIDS-Nepal approach is born of operating with a far lower support base, particularly in regard to ongoing support for the communities it impacts. It has been forced to innovate and develop energy service solutions in order to maximise end impacts, within a highly constrained delivery model.

The holistic approach it has developed has allowed it to make deeper immediate in-roads into some of the primary intended impact areas identified for both programmes – reducing fuelwood consumption and thereby improvement of domestic living conditions associated with fuelwood consumption. The programme has focussed chiefly on end impacts – namely health and hygiene benefits, environmental benefits and social impacts – and has mixed and matched programme components to achieve this.

Two of the focus areas within this – eliminating smoke within residences and reducing fuelwood consumption – have been delivered developing a lower cost[xxii], long lifetime smokeless metal stove, rather than displacing fuelwood consumption with electricity or other fuel. In conjunction with WLED lighting solution, this has effectively rendered Humla residences smoke free, and with 1/3 to 2/3 less burden of collecting fuelwood, where it has been delivered.

In this approach, the RIDS-Nepal programme has achieved significantly greater impacts in regards to preventative health, environmental and social benefits related to improving fuelwood supported energy services than is ever likely to result from the sole delivery of a streamlined electrification programme. It has achieved this at costs per capita that are almost certainly an order of magnitude lower than any other streamlined electrification programme carried out in the Himalayan terrain.

While the ADB-Bhutan programme is suitable approach for its context, it could be improved through adopting more of a focus on achieving the end benefits rather than electrification only. Moreover, its benefits could be maximised by looking at adopting some of the holistic approach of RIDS-Nepal which achieves higher bang for buck impacts.

Specific ideas and instruments can also be taken from the RIDS-Nepal approach, including;

- focus on smokeless stoves;
- focus on energy efficiency (consideration of achieving the same task with lower energy, such as WLED lighting for less critical lit areas, in order to make electricity-use more affordable for end-users / subsidies more sustainable);
- considering a broader range of energy service options in concert;
- consider establishment of village or gewog-based bathing houses run on electric hot water;
- support establishment of local industry to manufacture safe electric hot water devices with capacity to provide volumes for bathing;
- development of internal cottage industries to lower costs of devices and improve domestic consumption effects on balance of trade.

In many of these instances, relatively little effort by other areas of government could capitalise on the huge investment made already in rural electrification.

In conclusion, there is no doubt that the streamlined electrification approach has successfully provided significant quality of life improvements to the rural populace of Bhutan. Moreover it has achieved its goals of providing tangible benefits and equity in access to services through maximising its reach and speed of delivery. However, the end benefits at household level require specific focus, and could improve dramatically by adopting some of the holistic approach of RIDS – Nepal, which achieves far higher “bang for buck” impacts. This is most pertinent in regards to reducing fuelwood consumption, and the key associated environmental, social and preventative health benefits that electrification has targeted. This will require a whole of government approach.

Conversely, the RIDS-Nepal programme suffers from relatively lengthy overall timeframe of delivery and reach. This is understandable, and possibly intractable in the short term, given its context of operation including lack of support from the Nepalese government and limited resourcing. The programme also uses an incredibly low level of electricity provision within its delivery, in order to

[xxii] This has included development of a Nepalese cottage industry to produce SMS, in order to ensure high efficiency, cultural appropriateness and robustness of design as well as bringing down price.

provide more sustainable maintenance, however this limits the total benefits the programme can yield over the longer term, in regard to any electrical services beyond lighting. Perhaps a more modular approach to construction of centralised power systems in family of 4+ could alleviate this.

7.0 Bibliography

The Bibliography contains the principle literature sources used in compilation of this Dissertation. A far wider array of secondary literature sources was considered within the literature review conducted – where useful examples and findings were incorporated within the research from either primary or secondary literature sources, these have been referenced within the main text, to the referencing section at the end of the dissertation.

Principle Literature Sources

- Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
- Mann, Jason 2009 - "The impact on respiratory ailments through reduction of indoor air pollution by smokeless metal stove and solar lighting: Results of a study in rural Nepal" - , Centre for International Health, November 2009
- Naylor, Gavin 2009 - "Changing Well-being and Livelihoods: An Examination of the Impacts of Smokeless Metal Stoves on Individuals and Communities in Humla, Nepal" - Dissertation towards the fulfilment of the degree of BSc Human and Physical Geography, University of Reading- February 2009
- RIDS-Nepal website - http://www.rids-nepal.org/ accessed throughout February – October 2012, including password access data section.
- Ministry of Economic Affairs, Royal Government of Bhutan 2011 – "Ministry of Economic Affairs Annual Report to the 7th Session of the First Parliament" – June 2011
- Ministry of Economic Affairs, Royal Government of Bhutan 2012 – "Ministry of Economic Affairs 10th FYP Midterm Review"
- Bhutan's National Five Year Plans, available at: http://www.gnhc.gov.bt/five-year-plan/ throughout January-October 2012; principally;
    - EIGHTH FIVE YEAR PLAN – 1997- 2002, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 1997
    - NINTH FIVE YEAR PLAN – 2002- 2007, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 2002
    - TENTH FIVE YEAR PLAN - 2008-2013, Volume 1 [Policy] & 2 [Programme Profile]Gross National Happiness Commission, Royal Government of Bhutan, 2007/8
- Nepal's National Five Year Plans, available at: http://www.npc.gov.np/en/plans-programs throughout January - October 2012; principally;
    - EIGHTH FIVE YEAR PLAN – 1992- 1997, National Planning Commission, His Majesty's Government of Nepal – June 1992
    - TENTH FIVE YEAR PLAN – 2002- 2007, National Planning Commission, His Majesty's Government of Nepal – March 2002
    - THREE YEARS INTERIM PLAN – 2008-2010, National Planning Commission, The People's Government of Nepal – January 2008
- Bhutan Power Corporation website; http://www.bpc.bt

- Gross National Happiness Commission Website, Royal Government of Bhutan; http://www.gnhc.gov.bt/, accessed throughout February-October 2012
- Ministry of Economic Affairs, Dept. of Renewable Energy, Royal Government of Bhutan; http://www.moea.gov.bt/?page_id=64, accessed throughout February-July 2012
- Asian Development Bank Website; http://www.adb.org/ , primarily;
    - ADB Country operations business plans: http://www.adb.org/documents/series/country-operations-business-plans
    - ADB Member country profile – Bhutan: http://beta.adb.org/countries/bhutan/main
    - ADB Member country profile – Nepal: http://beta.adb.org/countries/nepal/overview
- Japanese International Cooperation Agency (JICA) website: http://www.jica.go.jp/english/index.html , primarily;
    - JICA country profile Bhutan: http://www.jica.go.jp/bhutan/english/index.html
    - JICA country profile Nepal: http://www.jica.go.jp/Nepal/english/index.html
    - JICA rural electrification search results: http://www.jica.go.jp/english/searchResults/index.html?q=rural%20electrification
- National Planning Commission, Government of Nepal; http://www.npc.gov.np/en/plans-programs/eco.php accessed throughout February-July 2012

8.0 Appendices

Appendix One – Extract from the 10th FYP Mid Term Review [July 2008- June 2010] - Ministry of Economic Affairs [Royal Government of Bhutan] November 2010

Table 9 – Progress of Rural Electrification compared to the initial plan

Fiscal Year	Initial Plan	Achievement & Revised Plan			
		On-Grid	Fill-in RE	Off-Grid	Total HHs
2008-09	1,635	0	1,000	878	1,878
2009-10	15,366	561	1,388	1,087	3,036
2010-11	2,285	15,373	1,210	735	17,318
2011-12	19,171	800	1,210	882	2,892
2012-13	5,494	17,504	1,211	112	18,827
TOTAL	**43,951**	**34,238**	**6,019**	**3,694**	**43,951**

30

Table 10 – Break-down of funding status for all rural electrification projects

Electricity for All by 2013 – Funding Status

Sl. No.	Project	HHs	Donor	RGoB/BPC	Fund Status*
			Nu. in million		
A	On-Grid	40,257	4,216.229	1,917.164	
1	ADB- IV project	8,767	1,095.888	287.844	Secured
2	JICA/JBIC-I Project	15,712	1,439.340	840.460	Secured
3	ACB-VI	800	102.940	31.200	Secured
4	ADB-V project	5,075	607.200	83.720	Secured
5	JICA-II Project	3,665	905.861	146.275	To be secured
6	ACB-VII	219	65.000	26.082	Secured
7	RE Fill-in	6,019		501.583	Secured
B	Off-Grid	3,694	190.440		
1	Solar	3,582	131.68		Secured
2	Micro Hydro	112	58.76		Not secured
TOTAL		43,951	4,406.669	1,917.16	
*82.4% of the total Fund Secured					

31

Appendix Two - Extract from the 10th FYP [Royal Government of Bhutan] from summary report of progress achieved during 9th FYP.

Table 11 – Existing Solar PV Systems installed in Bhutan by Royal Government of Bhutan

Dzongkhags	Total modules	Total nos of systems	Total Wp	Average Wp per a system
Bumthang	369	184	18,806	102.2
Chukha	118	59	6,490	110.0
Dagana	106	53	5,788	109.2
Gasa	650	325	33,440	102.9
Haa	344	172	18,920	110.0
Lhuentse	185	92	10,036	109.1
Mongar	168	84	9,200	109.5
Punakha	191	96	10,358	108.5
Paro	173	87	9,426	108.3
Pema Gatshel	205	103	10,533	102.3
Samtse	112	56	6,160	110.0
Sarpang	102	51	5,610	110.0
Samdrup Jongkhar	226	113	12,220	108.1
Thimphu	436	218	22,524	103.3
Trongsa	209	105	11,222	107.4
Tsirang	112	56	6,076	108.5
Trashigang	208	104	10,924	105.0
Trashi Yangtse	204	102	11,025	108.1
Wangdue	347	249	18,369	73.8
Zhemgang	158	79	7,988	101.1
Total	**4,623**	**2,387**	**245,115**	**102.7**

Source: Power Data 2006, DOE

Appendix 3 - Extract from the 10th FYP [Royal Government of Bhutan] from Chapter 8, Rural Electrification

Table 12 - Electricity Tariffs for new customers connected within ADB-IV, in 2009 prices.

Table 43: Base Tariff Rates for calculation of FIRR

For Low Voltage – Domestic Customers	
Energy charge Nu./kWh Upto 80 kWh/month	0.75
Energy charge Nu./kWh 81 to 300 kWh/month	1.4
Energy charge Nu./kWh above 301 kWh/month	1.85
For Low Voltage - Bulk Customers	
Energy charge Nu./kWh	1.85
For Medium Voltage Customers (33/11/6.6 kV)	
Energy charge Nu./kWh	1.55
Demand charge Nu./kW/Month	85

(Source – BPC Tariff Schedule)

Appendix 4 – ADB support for Rural Electrification in Asia

The ADB has provided support to promote Rural Electrification in developing countries throughout Asia. Such ADB loans and grants between 1989 and 2009 are detailed in Table 13 and Table 14 respectively, with Nepal and Bhutan highlighted.[xxiii]

Table 13 - ADB Loans for Rural Electrification

Table A1.2: ADB Loans for Rural Electrification, 1989–2009
($ million)

Loan No.	Project Name	No. of Projects	Funding Source	Amount ($ million)	Date Approved	Purpose
Afghanistan		1		26.5		
2165	Power Transmission and Distribution		ADF	26.5	14-Apr-05	transmission and distribution
Bangladesh		5		534.9		
1356	Rural Electrification		ADF	50.0	30-May-95	distribution and capacity building
1884	West Zone Power System Development		ADF	60.2	17-Dec-01	transmission and distribution
1885	West Zone Power System Development		OCR	138.7	17-Dec-01	transmission and distribution
2038	Power Sector Development Program (Program Loan)		OCR	100.0	10-Dec-03	generation, transmission, distribution and reforms
2039	Power Sector Development Program (Project Loan)		OCR	186.0	10-Dec-03	
Bhutan		5		106.9		
1375	Rural Electrification		ADF	7.5	19-Sep-95	distribution and capacity building
1712	Sustainable Rural Electrification		ADF	10.0	25-Nov-99	distribution and capacity building
2009	Rural Electrification and Network Expansion		ADF	9.4	30-Sep-03	generation and distribution
2463	Green Power Development		OCR	51.0	29-Oct-08	generation
2464	Green Power Development		ADF	29.0	29-Oct-08	generation
Cambodia		2		64.3		
2052	Greater Mekong Subregion Transmission		ADF	44.3	15-Dec-03	transmission, distribution and capacity building
2261	Second Power Transmission and Distribution		ADF	20.0	4-Oct-06	transmission, distribution and capacity building
India		2		119.4		
2592	Assam Power Sector Enhancement Investment Program - Tranche 1		OCR	60.3	27-Nov-09	transmission, distribution and capacity building
2596	Himachal Pradesh Clean Energy Development Investment Program - Tranche 2		OCR	59.1	8-Dec-09	generation and capacity building
Indonesia		1		161.0		
1982	Renewable Energy Development Sector		OCR	161.0	19-Dec-02	generation, distribution and financing
Lao People's Democratic Republic		3		64.0		
1308	Nam Ngum-Luang Prabang Power Transmission (Supplementary)		ADF	4.0	30-Aug-94	transmission and distribution
1558	Power Transmission and Distribution		ADF	30.0	30-Sep-97	transmission and distribution
2005	Northern Area Rural Power Distribution		ADF	30.0	18-Sep-03	distribution and capacity building
Nepal		3		166.0		
1011	Seventh Power		ADF	51.0	11-Jan-90	transmission and distribution
1732	Rural Electrification, Distribution and Transmission		ADF	50.0	21-Dec-99	generation
2587	Energy Access and Efficiency Improvement		ADF	65.0	27-Nov-09	transmission, distribution and capacity building
Pakistan		2		60.0		
2552	Energy Efficiency Investment Program - Tranche 1		OCR	40.0	22-Sep-09	transmission, distribution and capacity building
2553	Energy Efficiency Investment Program - Tranche 1		ADF	20.0	22-Sep-09	transmission, distribution and capacity building
People's Republic of China		2		200.0		
1644	Yunnan Dachaoshan Power Transmission		OCR	100.0	27-Nov-98	transmission and distribution
1901	Shen-Da Power Transmission and Grid Rehabilitation		OCR	100.0	20-Dec-01	distribution and capacity building
Sri Lanka		4		314.3		
1021	Power System Expansion (Sector Loan)		ADF	74.3	31-May-90	transmission and distribution
1414	Second Power System Expansion (Sector)		ADF	80.0	14-Dec-95	transmission and distribution
2518	Clean Energy and Access Improvement		OCR	135.0	14-Apr-09	generation, transmission, distribution and DSM
2519	Clean Energy and Access Improvement		ADF	25.0	14-Apr-09	generation, transmission, distribution and DSM
Thailand		1		100.0		
1429	Rural Electrification		OCR	100.0	23-Jan-96	distribution
Viet Nam		3		1,153.9		
1585	Central and Southern Viet Nam Power Distribution		ADF	100.0	27-Nov-97	transmission, distribution and capacity building
2517	Renewable Energy Development Network Expansion and Rehabilitation for Remote Communes Sector		ADF	151.0	30-Mar-09	generation and financing
2610	Mong Duong 1 Thermal Power Project - Tranche 2		OCR	902.85	21-Dec-09	generation
	Total	34		3,071.15		

ADB = Asian Development Bank, ADF = Asian Development Fund, DSM = demand side management, OCR = ordinary capital resources.
Source: ADB loan, technical assistance, and grant databases.

[xxiii] Reproduced from Appendix One, ADB – Evaluation Study – "Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life?" Reference Number: IES: BHU 2010-27 Impact Evaluation Study Number: 26194 August 2010 – Independent Evaluation Department, ADB.

Table 14- ADB Grants for Rural Electrification in Asia

Table A1.6: ADB Grants for Rural Electrification, 1989–2009

Grant No.	Project Name	No. of Projects	Source of Funding	Amount ($ million)	Date Approved	Purpose
Afghanistan		1		23.5		
0004	Power Transmission and Distribution		ADF	23.5	14-Apr-05	transmission and distribution
Bhutan		3		27.3		
0119	Green Power Development		CEFPF	1.0	29-Oct-08	distribution
0119	Green Power Development		ADF	25.3	29-Oct-08	distribution
9093	Rural Electricians Training Program		JFPR	1.0	25-May-06	
Mongolia		1		2.4		
9139	Demonstration Project for Improved Electricity Services to the Low-Income		JFPR	2.4	9-Sep-09	transmission, distribution, capacity building and financial services preparation
Nepal		2		4.5		
0182	Energy Access and Efficiency Improvement		CCF	0.3	27-Nov-09	transmission and distribution
0183	Energy Access and Efficiency Improvement		CEF	4.2	28-Nov-09	transmission and distribution
Philippines		1		1.5		
9042	Renewable Energy and Livelihood Development Project for the Poor in		JFPR	1.5	19-Jan-04	generation, distribution, financing and reforms
Sri Lanka		2		3.7		
0149	Clean Energy and Access Improvement		SF	2.2	6-Oct-09	distribution
9045	Power Fund for the Poor		JFPR	1.5	7-Apr-04	capacity building and financing
Tajikistan		1		2.0		
9089	Community-Based Rural Power Supply		JFPR	2.0	15-Mar-06	generation, reforms and DSM
	Total	11		64.9		

ADB = Asian Development Bank, ADF = Asian Development Fund, CCF = Climate Change Fund, CEF = Clean Energy Fund, CEFPF = Clean Energy Financing Partnership Facility, DSM = demand side management, JFPR = Japan Fund for Poverty Reduction, SF = special fund.
Source: ADB loan, technical assistance, and grant databases.

In addition to these assistance mechanisms, the ADB has provided technical assistance to rural electrification efforts totalling $25.4 million between 1989-2009, including $4.245million to Bhutan, and $1.050million to Nepal.

Appendix 5 – ADB Energy Projects within Nepal[69]

ADB has offered sponsorship of the following energy related projects in Nepal;

Country	Project Name	Types of Assistance	Approval Numbers	Status	Approval Date
Nepal	45126-001 Scaling Up Renewable Energy Project (http://www.adb.org/projects/45126-001/main?ref=countries/nepal/projects)	TA	8081	Approved	28 May 2012
Nepal	41155-013 Electricity Transmission Expansion and Supply Improvement Project (http://www.adb.org/projects/41155-013/main?ref=countries/nepal/projects)	Grant Grant Loan TA	0270 0271 2808 7923	Approved	15 Nov 2011
Nepal	45126-002 Scaling Up Micro and Mini Renewable Energy Initiatives (http://www.adb.org/projects/45126-002/main?ref=countries/nepal/projects)	TA	7807	Approved	17 May 2011
Nepal	45129-001 Scaling Up Small Hydro Power Projects (http://www.adb.org/projects/45129-001/main?ref=countries/nepal/projects)	TA	7816	Approved	13 May 2011
Nepal	41155-012 Energy Access and Efficiency Improvement Project II (http://www.adb.org/projects/41155-012/main?ref=countries/nepal/projects)	TA	7666	Approved	26 Nov 2010
Nepal	41154-012 Energy Sector Capacity Building (http://www.adb.org/projects/41154-012/main?ref=countries/nepal/projects)	TA	7628	Approved	27 Oct 2010
Nepal	43281-012 Preparing Hydropower Development for Energy Crisis (http://www.adb.org/projects/43281-012/main?ref=countries/nepal/projects)	TA	7590	Approved	2 Sep 2010
Nepal	43281-022 Detailed Engineering Study for the Upper Seti Hydropower Project (http://www.adb.org/projects/43281-022/main?ref=countries/nepal/projects)	Grant	0215	Approved	2 Sep 2010
Nepal	43299-012 Increasing Access to Energy in Rural Nepal (http://www.adb.org/projects/43299-012/main?ref=countries/nepal/projects)	TA	7504	Approved	5 Mar 2010
Nepal	40553-013 Energy Access and Efficiency Improvement Project (http://www.adb.org/projects/40553-013/main?ref=countries/nepal/projects)	Grant Grant Loan	0182 0183 2587	Approved	27 Nov 2009
Nepal	40553-012 Preparing Electricity Connectivity and Energy Efficiency Project I (http://www.adb.org/projects/40553-012/main?ref=countries/nepal/projects)	TA	7176	Closed / Terminated	19 Nov 2008
Nepal	42119-012 Transmission and Distribution Project (http://www.adb.org/projects/42119-012/main?ref=countries/nepal/projects)	TA	7076	Closed / Terminated	21 Apr 2008
Nepal	41025-012 Promoting Private Sector Participation in the Power Sector (http://www.adb.org/projects/41025-012/main?ref=countries/nepal/projects)	TA	4997	Closed / Terminated	3 Dec 2007
Nepal	37196-012 Restructuring of Nepal Electricity Authority (http://www.adb.org/projects/37196-012/main?ref=countries/nepal/projects)	TA	4492	Closed / Terminated	18 Dec 2004
Nepal	35349-012 Rural Electrification and Renewable Energy Project (http://www.adb.org/projects/35349-012/main?ref=countries/nepal/projects)	TA	4493	Closed / Terminated	17 Dec 2004
Nepal	32241-012 Power Sector Reforms in Nepal (http://www.adb.org/projects/32241-012/main?ref=countries/nepal/projects)	TA	3552	Closed / Terminated	27 Nov 2000
Nepal	29471-013 Rural Electrification, Distribution and Transmission Project (http://www.adb.org/projects/29471-013/main?ref=countries/nepal/projects)	Loan	1732	Closed / Terminated	21 Dec 1999
Nepal	33336-012 Transmission Planning in the Kathmandu Valley (http://www.adb.org/projects/33336-012/main?ref=countries/nepal/projects)			Closed / Terminated	10 May 1999
Nepal	45126-003 Scaling Up Renewable Energy Project (http://www.adb.org/projects/45126-003/main?ref=countries/nepal/projects)	Loan	-	Proposed	
Nepal	43281-013 Tanahu Hydropower Project (http://www.adb.org/projects/43281-013/main?ref=countries/nepal/projects)	Loan	-	Proposed	

Appendix 6 – Description of Bhutan's Rural Electrification Programme in Tenth Five Year Plan[70]

MEA/09: RURAL ELECTRIFICATION PROGRAMME

A. Overview

1	Sector	:	Energy & Power
2	Linkage to National Development Objectives & Strategies	:	Vitalizing Industry and Synergizing Integrated Rural Urban Development by providing clean energy services and enhancing national energy security
3	Expected Results	:	Expanded coverage of rural electrification through grid supply and provision of grid electricity access for new and left-out/fill-in households.
4	Relevant MDG & SDG	:	MDG Goal 1: Eradicate extreme poverty and hunger SDG Goal 1 & 2: Eradication of hunger poverty & Halve proportion of population in poverty by 2010 MDG Goal 7: TARGET 9: Integrate the principles of sustainable development into country policies and and reverse the loss of environmental resources SDG Goal 4: Ensure a robust pro-poor growth process SDG Goal 5: Strengthen connectivity of poorer regions and of poor as social groups SDG Goal 6: Reduce social and institutional vulnerabilities of the poor, women and children SDG Goal 17 Acceptable level of forest cover SDG Goal 18 Acceptable level of water and soil quality
5	Donor Agency	:	
6	Target Group	:	All Bhutanese households/ Rural Communities
7	Scope	:	Nation wide
8	Status-Ongoing/New	:	New/Ongoing
9	Timeframe	:	Five years (2008-2013)
10	Indicative Capital Cost	:	Nu. 3,727.000 m
11	External Financing Required	:	Nu. 3,727.000 m
12	Executing Agency	:	Department of Energy, MoEA
13	Implementing Agencies	:	Bhutan Power Corporation Limited and Communities
14	Documents Available	:	RE Mater Plan; Power System Master Plan; Integrated Energy Management Master Plan; Sector Tenth Plan

References

[1] United Nations Development Programme, United Nations Department of Economic and Social Affairs & World Energy Council: "World Energy Assessment: Overview 2004 Update"
[2] *Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life?* Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[3] 10th FYP Mid Term Review [July 2008- June 2010] - Ministry of Economic Affairs November 2010
[4] The WORLD FACTBOOK - CENTRAL INTELLIGENCE AGENCY: https://www.cia.gov/library/publications/the-world-factbook/geos/np.html
[5] IBID
[6] The WORLD FACTBOOK - CENTRAL INTELLIGENCE AGENCY: https://www.cia.gov/library/publications/the-world-factbook/geos/bt.html
[7] IBID
[8] http://www.globalsecurity.org/military/world/war/nepal_insurgency.htm, accessed May 2012.
[9] IBID
[10] The WORLD FACTBOOK - CENTRAL INTELLIGENCE AGENCY: https://www.cia.gov/library/publications/the-world-factbook/geos/np.html, https://www.cia.gov/library/publications/the-world-factbook/geos/bt.html
[11] EIGHTH FIVE YEAR PLAN – 1985- 1990, National Planning Commission, His Majesty's Government of Nepal March 1985
[12] EIGHTH FIVE YEAR PLAN – 1992- 1997, National Planning Commission, His Majesty's Government of Nepal – June 1992 - Chapter 16.
[13] EIGHTH FIVE YEAR PLAN – 1992- 1997, National Planning Commission, His Majesty's Government of Nepal – June 1992 - Chapter 16– Expenditure Details Table
[14] EIGHTH FIVE YEAR PLAN – 1992- 1997, National Planning Commission, His Majesty's Government of Nepal – June 1992 - Chapter 16
[15] EIGHTH FIVE YEAR PLAN – 1992- 1997, National Planning Commission, His Majesty's Government of Nepal – June 1992 - Appendix 2 - Electric Energy Demand and Supply Balance: "Visual Chart A", "Visual Chart B"
[16] TENTH FIVE YEAR PLAN – 2002- 2007, National Planning Commission, His Majesty's Government of Nepal – March 2002 – Chapter 16; Table No. 16.1 Targets and Achievements of the Ninth Plan
[17] THREE YEARS INTERIM PLAN – 2008-2010, National Planning Commission, The People's Government of Nepal – January 2008 - Pg 149
[18] Annual Report: Nepalese Electricity Authority - August 2011
[19] "Nepal Status Paper - United Nations Conference on Sustainable Development 2012 (Rio+20) Synopsis" - National Planning Commission, Government of Nepal , Singhadurbar, Kathmandu April 2012
[20] SIXTH FIVE YEAR PLAN – 1987- 1992, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 1986
[21] SEVENTH FIVE YEAR PLAN – 1992- 1997, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 1992
[22] IBID
[23] NINTH FIVE YEAR PLAN – 2002- 2007, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 2002
[24] IBID
[25] TENTH FIVE YEAR PLAN - 2008-2013, Gross National Happiness Commission, Royal Government of Bhutan, 2007/8 - Volume 2 MEA/09: RURAL ELECTRIFICATION PROGRAMME – Section B
[26] TENTH FIVE YEAR PLAN - 2008-2013, Gross National Happiness Commission, Royal Government of Bhutan, 2007/8 – Volume 1 Chapter 8
[27] - TENTH FIVE YEAR PLAN - 2008-2013, Gross National Happiness Commission, Royal Government of Bhutan, 2007/8 - Volume 2 MEA/09: RURAL ELECTRIFICATION PROGRAMME – Section E
[28] IBID
[29] TENTH FIVE YEAR PLAN - 2008-2013, Gross National Happiness Commission, Royal Government of Bhutan, 2007/8 - Volume 2 MEA/09: RURAL ELECTRIFICATION PROGRAMME – Section B
[30] TENTH FIVE YEAR PLAN - 2008-2013, Gross National Happiness Commission, Royal Government of Bhutan, 2007/8 - Volume 2 MEA/09: RURAL ELECTRIFICATION PROGRAMME – Section C, E
[31] Bhutan 10th FYP Mid Term Review [July 2008- June 2010] - Ministry of Economic Affairs November 2010

[32] Bhutan Ministry of Economic Affairs CY10 Annual Report to the 7th Session of the First Parliament, March 2011
[33] THREE YEARS INTERIM PLAN – 2008-2010, National Planning Commission, The People's Government of Nepal – January 2008 – Chapter 7, "Peace, Reconstruction, Rehabilitation and Reintegration".
[34] IBID
[35] Country Operations Business Plan – Nepal 2012-1014 – Asian Development Bank [September 2011]
[36] Nepal Electricity Authority – Annual Report 2010
[37] Technical Assistance Consultant's Report : "Bhutan: Preparing the Bhutan Power Development Project" – PwC prepared for ADB : Project Number: 37399 February 2009
[38] Dorji, Urmee & Jennings – "Options for off-grid electrification in the Kingdom of Bhutan" - School of Engineering and Energy, Murdoch University, Murdoch Drive, Murdoch WA 6150, Australia; published in Renewable Energy 45 (2012) 51e58
[39] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[40] Urmee & Harries, 2008/9 – "A survey of solar PV program implementers in Asia and the Pacific regions", Research Institute of Sustainable Energy (RISE), Murdoch University, Murdoch Drive, WA-6150, Australia published in Energy for Sustainable Development 13 (2009) 24–32
[41] Ibid.
[42] Zomers, Adriaan.N "Rural Electrification" - 2001 PHD Thesis University of Twente
[43] Urmee, Harries & Schlapfer –"Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific", published in Renewable Energy 34 (2009) 354–357.
[44] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? - ADB
[45] World Bank: Washington; DC; Roddis, S. 2000. Poverty Reduction and Energy: The Links Between Electricity and Education.
[46] Naylor, Gavin 2009 - "Changing Well-being and Livelihoods: An Examination of the Impacts of Smokeless Metal Stoves on Individuals and Communities in Humla, Nepal" - Dissertation towards the fulfilment of the degree of BSc Human and Physical Geography, University of Reading- February 2009
[47] IBID
[48] IBID
[49] World Health Organisation; http://www.who.int/water_sanitation_health/hygiene/en/
[50] Mann, J 2009 - "The impact on respiratory ailments through reduction of indoor air pollution by smokeless metal stove and solar lighting: Results of a study in rural Nepal" - Centre for International Health, November 2009
[51] IBID
[52]Naylor, Gavin 2009 - "Changing Well-being and Livelihoods: An Examination of the Impacts of Smokeless Metal Stoves on Individuals and Communities in Humla, Nepal" - Dissertation towards the fulfilment of the degree of BSc Human and Physical Geography, University of Reading- February 2009
[53] World Health Organisation 2012 – "Progress on drinking water and sanitation" - available at: http://www.who.int/water_sanitation_health/monitoring/en/
[54] RIDS-Nepal website: http://www.rids-nepal.org/ accessed June 2012.
[55] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[56] EIGHTH FIVE YEAR PLAN – 1997- 2002, Department of Planning, Ministry of Finance, Royal Government of Bhutan, 1997.
[57] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[58] IBID
[59] IBID
[60] IBID
[61] Urmee and Harries 2011 - "Determinants of the success and sustainability of Bangladesh's SHS program" –, Renewable Energy 36 (2011) 2822e2830 - 10 May 2011

[62] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[63] Zahnd, A – Professional expert opinion, as published in Case Study of a Solar Photovoltaic Elementary Lightning System for a Poor and Remote Mountain Village in Nepal, MSc in Renewable Energy Dissertation
[64] Asian Development Bank's Assistance for Rural Electrification in Bhutan—Does Electrification Improve the Quality of Rural Life? Reference Number: IES: BHU 2010-27 - Impact Evaluation Study Number: 26194 - August 2010 [Asian Development Bank Evaluation Report]
[65] IBID
[66] IBID
[67] IBID
[68] Naylor, Gavin 2009 - "Changing Well-being and Livelihoods: An Examination of the Impacts of Smokeless Metal Stoves on Individuals and Communities in Humla, Nepal" - Dissertation towards the fulfilment of the degree of BSc Human and Physical Geography, University of Reading- February 2009
[69] http://www.adb.org/projects/search/499%2C21270?ref=countries%2Fnepal%2Fprojects
[70] Bhutan 10FYP 2007-8 - Volume 2 MEA/09: RURAL ELECTRIFICATION PROGRAMME – Section A